The saga of CT coronary angiography continues and new exciting developments are on the horizon. We have witnessed the astounding rapid developments in CT technology from 4-, 16-, 64-, 128-, 256-, to 320-slice acquisition, with tube rotational speed increasing from 250 to 87 ms and with ever decreasing radiation exposure from ~20 to <1 mSv with the preservation of image quality.

One would think that further developments would not be possible but, lo and behold, at present we see the development of CT coronary angiography combined with CT functional imaging of coronary obstructions.

One of the major limitations of CT coronary angiography is the fact that CTCA cannot accurately predict the functional severity of a coronary obstruction and the detection of a coronary diameter stenosis >50% often requires further non-invasive or invasive functional testing. This is not unexpected because the diameter either derived from CT coronary angiography, or also from invasive coronary angiography (with a better temporal and spatial resolution), irrespective of visual or quantitative assessment, is a poor predictor of the functional severity of a coronary obstruction.1 This issue is further complicated by the tendency to overestimate the stenosis severity by CTCA or by the sometimes occurring inability to grade the stenosis severity due to severe calcification, the presence of a coronary stent or motion artefact. In addition anatomy cannot account for endothelial dysfunction, coronary microvascular disease, or the presence of collateral circulation that affects the functional severity of a coronary obstruction.

The severity of obstructive CAD is defined both by vessel morphology and coronary blood flow. The combined information of the coronary anatomic severity and functional severity of an obstruction is now considered crucial for optimal decision-making in stable patients with suspected CAD.

The diagnostic performance of non-invasive testing in patients with suspected CAD was dramatically increased using the combination of anatomical and functional imaging by hybrid PET/CT.2

The addition of CT functional stenosis imaging to CT coronary angiography would blow new life in CT coronary angiography.

Recently studies demonstrated the feasibility and reliability of adenosine stress-induced CT myocardial perfusion to analyse the effect of a coronary stenosis on the myocardial blood flow.3,4 The method is in its early stage and many obstacles need to be resolved, among others the most pressing being the (unacceptable) increased radiation dose and collection of sufficient data points to determine a precise time attenuation curve before its use in clinical practice.

An exciting novel method, CT-FFR, has recently been introduced into clinical practice. This method allows the extraction of ‘stress induced’ quantitative functional information from rest anatomic CT coronary data sets. The method uses computational fluid dynamics with simulated hyperaemia to calculate the fractional flow reserve of a coronary stenosis. CT-FFR correlates well with invasive-derived FFR measurements in patients with suspected CAD.5 One of the drawbacks at this point of time is that CT-FFR needs extreme computational ability and analysis time which hampers widespread dissemination.

Another new CT approach is the measurement of the density values of the passage of contrast bolus through the coronary arteries. This allows the assessment of the gradient of contrast attenuation along the course of the coronary artery. The coronary contrast density depends on the intracoronary blood flow and from the attenuation values one can derive information about the ‘coronary blood flow’ and thus about the functional severity of a coronary stenosis.6–8 The data can be extracted from a simple CTCA data set.

Earlier reports have shown that intracoronary attenuation gradient analysis correlated with quantitative CT coronary angiography and invasive coronary angiography obtained TIMI flow measurements.6–8 However, a study comparing the functional significance of intracoronary gradient analysis with the functional standard of reference intracoronary FFR was lacking.

In this journal, Choi et al.9 present a validation study comparing intracoronary FFR (FFR <0.80) with two intracoronary gradient analysis methods: the transluminal attenuation gradient (TAG)
and the corrected coronary opacification (CCO), to assess the diagnostic accuracy of the functional significance of either method. They examined 97 major epicardial coronary arteries available from 63 patients. CTCA was performed with 64 slice CT scanners. TAG was determined from the change in attenuation (HU) per 10-mm length of the coronary artery and defined as the regression coefficient between attenuation and length from the ostium. The sensitivity, specificity, positive and negative predictive value on a per vessel basis of TAG was 48, 91, 79, and 71%, respectively, using FFR < 0.80 as a reference. The diagnostic performance with addition of TAG to CTCA was significantly improved (c-statistic 0.81 vs. 0.73; P = 0.025) but net reclassification after the addition of TAG to CTCA was not significant.

The combination of TAG and CT DS > 50% increased the sensitivity and negative predictive value (90% and 90%) but decreased the specificity and positive predictive value (63% and 63%).

The CCO was assessed by the analysis of CTCA axial slices. The intracoronary attenuation values were measured before and after the stenosis and were normalized to the attenuation values obtained from the aorta descendens from the same axial slice. The sensitivity, specificity, positive, and negative predictive value was 65, 61, 54, and 72%, respectively. The diagnostic performance did not increase after addition of CCO to CTCA (c-statistic 0.73–0.78 P = ns). Calculation of the net reclassification index after addition of CCO to CTCA revealed that 9.3% (P = 0.04) of the patients were not correctly classified.

The overall result of this study is somewhat disappointing because the diagnostic accuracy of TAG and CCO was only moderate in comparison with FFR. Several reasons may explain the relatively moderate correlation. TAG and CCO were measured during a resting state, whereas invasive FFR is measured during adenosine-induced hyperaemia. It is unknown if study results of TAG and CCO would better correlate with FFR under adenosine stress-induced measurements. However, CT coronary angiography under adenosine stress would increase the heart rate which may result in less image quality even using fast CT scanners. Attenuation values were acquired using 64-slice CTCA scanning from multiple cardiac cycles, which may have introduced a lack of temporal uniformity and variability in the contrast density. The use of a 320-slice CT scanner, instead of the 64-slice scanner used in the study of Choi et al., acquiring attenuation values over the entire coronary tree at the same time may be more appropriate to reduce the variability of these attenuation values. In addition, several other variables such as amount and injection rate of contrast, beam hardening, and blooming artefacts, partial volumeing, unfavourable signal to noise ratio, and contrast density non-linearity at side branches may affect contrast densities.

The advantage of this method is that it requires only one non-invasive CT coronary angiographic examination that provides anatomical and functional information about a coronary obstruction, also of complex, calcific or stented lesions. Having this additional functional option will be an indispensable boost for a wider clinical use of diagnostic CTCAs beyond the high reliability of the exclusion of the presence of significant CAD in stable patients with suspected CAD and may augment the predictive power of CTCAs. It may temper the debate between angiographers/interventionalists and imagers about the priority of anatomy or function and both groups may join forces to the advantage of patient management.

References