SIEMENS

White Paper | www.siemens.com/ct-cardiology

Superior specificity in cardiac CT

A powerful portfolio dedicated to minimize false positive findings in clinical routine

Philip Stenner, PhD

Answers for life.

Preamble

Coronary CT angiography (cCTA) is gaining more and more acceptance as a non-invasive test for symptomatic patients with a low to intermediate risk of having coronary artery disease (CAD). A 1,370 patient multi-center trial recently proved that cCTA allows for a safe discharge of patients with possible acute coronary syndrome.[1] Its high negative predictive value (NPV) has been proven in several trials and numerous studies have shown that patients with negative cCTAs also show no findings in invasive angiography.[2, 3, 4, 5] Although the latter still is regarded the gold standard for the assessment of coronary arteries, cCTA has proven to reduce the number of cardiac catheterizations in many institutions.[1]

Despite its strengths in ruling out CAD, cCTA up to now faced limitations. Studies have shown that its specificity may be thwarted under certain conditions: calcified lesions can cause blooming artifacts that hinder a reliable assessment of the vessel lumen.[5, 6] Motion artifacts caused by non-optimal scan protocols and inferior imaging techniques may further degrade its diagnostic capabilities and induce false positive findings that can cause unnecessary further testing or treatment.

Siemens has taken up the challenge and has continuously introduced a powerful set of product innovations designed to reduce false positives and boost specificity in cardiac imaging. As the two most important aspects to cardiac imaging are motion-free and sharp visualizations of the coronaries, the solutions are designed to maximize both temporal and spatial resolution.

Recently CT perfusion (CTP) has emerged as a promising technique to gain insight into the hemodynamic relevance of a stenosis. It has been shown that combining cCTA with CTP increases the specificity for detecting relevant stenoses.[7] To keep CTP as accurate as possible, Siemens has developed features that improve specificity also in this aspect of cardiac imaging.

Content

SOMATOM Definition AS+

heart rate: 62 bpm
temporal resolution: 150 ms
rotation time: 0.30 s
collimation: 128 x 0.6 mm
scan length: 137 mm
tube voltage: 120 kV
effective dose: 2.8 mSv

Courtesy University of Erlangen-Nuremberg, Erlangen, Germany

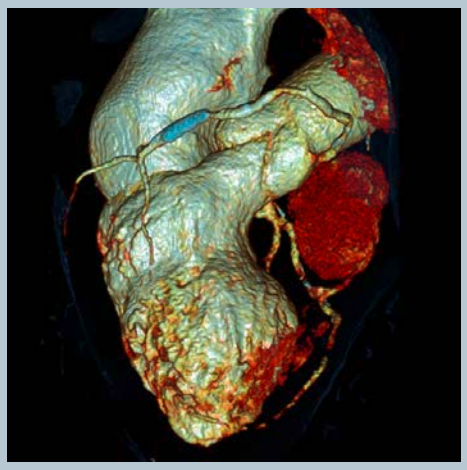
Get specific in diagnosing coronary artery disease

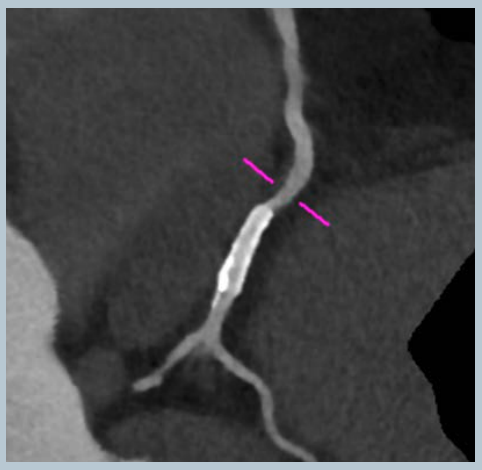
Highest temporal resolution to minimize motion artifacts

Available on
SOMATOM Definition Flash
SOMATOM Definition Edge
SOMATOM Definition AS

High gantry rotation speeds for high native temporal resolution without retrospective software corrections

Key to any imaging technique that aims at imaging moving objects is high temporal resolution. In cardiac imaging a motion-free visualization of the coronaries is essential for accurate diagnosis. If unaccounted for, motion artifacts affecting the coronaries may lead to overestimation of stenosis degree.[8] In single source computed tomography the temporal resolution in the isocenter is half the rotation time, as 180° of data are sufficient for image reconstruction. The SOMATOM Definition Edge, for instance, provides a rotation time of only 0.28 s yielding a native temporal resolution of 142 ms, allowing for robust imaging of the coronaries. Retrospective corrections that virtually improve the temporal resolution always rely on certain assumptions that can improve image quality in certain cases but can never be as robust as a fast "shutter speed" that only fast native data acquisition can provide.





SOMATOM Definition Flash

heart rate: 78 bpm

heart rate-independent temporal resolution: 75 ms

rotation time: 0.28 s

collimation: 128 x 0.6 mm

scan length: 103 mm

tube voltage: 120 kV

DLP: 243 mGycm

effective dose: 3.4 mSv

Courtesy German Heart Center, Munich, Germany

Dual Source CT – Flash speed for imaging of all patients and all heart rates

With the introduction of Dual Source CT (DSCT) Siemens has set the industry benchmark for native temporal resolution in mono-segment reconstruction. The SOMATOM Definition Flash provides a heart rate-independent temporal resolution of 75 ms that freezes the heart and reduces motion artifacts to an unparalleled minimum – the key to reliable coronary imaging.[2, 9, 10, 11]

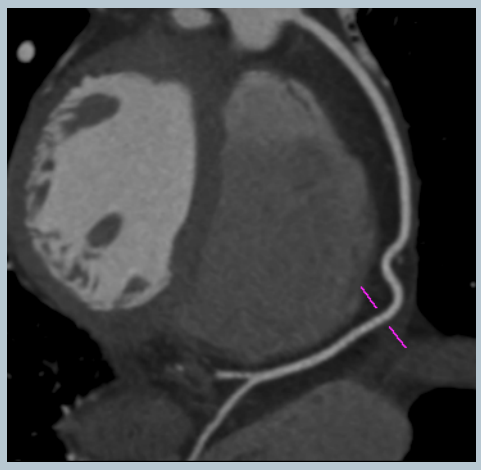
The literature shows a heightened specificity for DSCT systems.[12] The multicenter international MEDIC trial, a prominent study looking at the performance of DSCT in cCTA, shows that DSCT achieves excellent image quality – even without the use of beta blockers: it reported a sensitivity of 95% and a specificity of 95%.[13] The high-pitch spiral furthermore allows sub-mSv cCTAs in clinical routine.

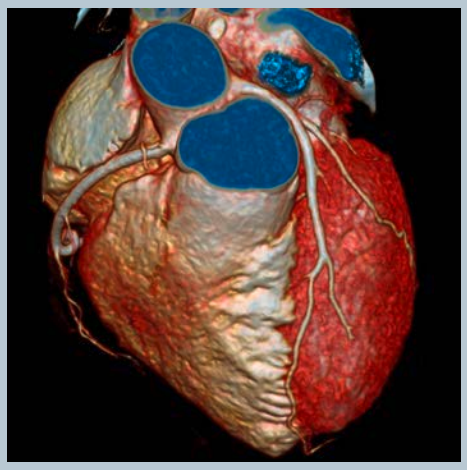
Available on
SOMATOM Definition Flash
SOMATOM Definition

SOMATOM Perspective

heart rate: 52 bpm
temporal resolution: 195 ms
rotation time: 0.48 s
collimation: 64 x 0.6 mm
scan length: 138 mm
tube voltage: 130 kV
DLP: 356 mGycm
effective dose: 4.9 mSv

Courtesy Shanghai Ruijin Hospital, Shanghai, China

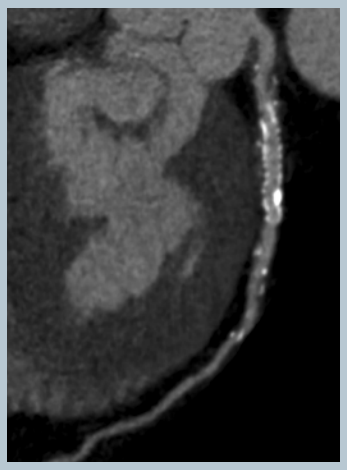




Available only on SOMATOM Perspective

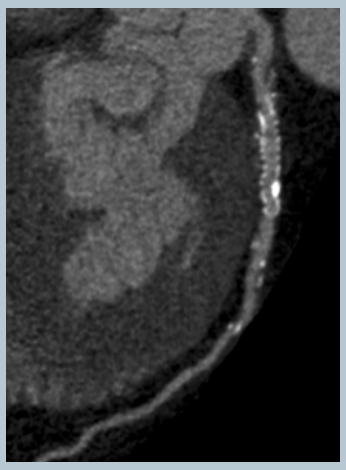
Improving temporal resolution with iTRIM

A high temporal resolution at the acquisition level is always favorable to any a posteriori methods that work on already acquired data. However, for scanners lacking high rotation speeds thus offering a decreased native temporal resolution, such an approach can be a compromise. In 2011, Siemens introduced the SOMATOM Perspective featuring a temporal resolution of as low as 195 ms at a gantry rotation time of 0.48 s. This is made possible by the novel iterative Resolution Improvement Method (iTRIM).[14] Here, regions prone to motion undergo an iterative reconstruction based on a subset of the originally acquired data, e.g. 140°. Stationary voxels are reconstructed using the total 180° of data. The final iTRIM image then is a combination of the two. As a standard cCTA is sufficient for this approach no multiphase acquisition is required which makes iTRIM dose-neutral. This new technique introduces cardiac imaging to scanners not primarily designed for cCTAs and to centers where cardiac imaging is not done on a routine basis – but where false positives of course shall also be reduced to a minimum.



SOMATOM Definition Flash

Regular reconstruction showing blooming artifacts around the stent struts and calcifications



SOMATOM Definition Flash

Reconstruction with the B46f kernel: the blooming is reduced and structures with high attenuation appear sharper

Unprecedented spatial resolution to provide clear vessel depiction

In addition to high temporal resolution high spatial resolution is important to fully grasp the anatomic detail of coronary arteries. Insufficient spatial resolution and partial-volume effects may cause an artificial thickening of highly attenuating structures, such as calcified lesions or stent struts. This so-called blooming artifact is responsible for the artificial lumen narrowing of stents. The resulting stenosis overestimation contributes significantly to the number of false positives in cardiac imaging.

Dedicated edge-enhancing kernels for coronary imaging

Even without iterative processes it is possible to obtain sharpest images of the coronaries while at the same time keeping the noise minimal. Siemens' edge-enhancing B46f reconstruction kernel on the one hand increases the visible lumen: a study showed that the artificial lumen narrowing was reduced from 37% to 29%.[15] On the other hand a dedicated edge-preserving filter reduces the image noise without affecting the vessel lumen. This powerful combination allows for a clear depiction of the coronaries and robust stent evaluation.

Available on
SOMATOM Definition Flash
SOMATOM Definition Edge
SOMATOM Definition AS

SOMATOM Definition Edge

heart rate: 67 bpm

heart rate-independent temporal resolution: 142 ms

rotation time: 0.28 s

collimation: 128 x 0.6 mm

spatial resolution: up to 0.30 mm with the Stellar Detector

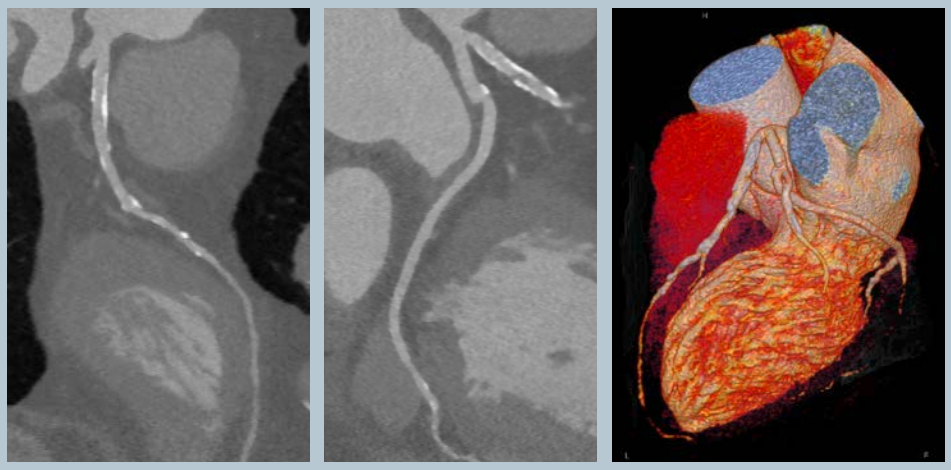
scan length: 99 mm

tube voltage: 100 kV

DLP: 250 mGycm

effective dose: 3.5 mSv

Courtesy Clinique CIMOP Bizet, Paris, France



Available on
SOMATOM Definition Flash
SOMATOM Definition Edge

Minimized blooming and enhanced vessel delineation with the Stellar Detector

In 2011, Siemens introduced the new Stellar Detector – the industry's first fully integrated detector for high resolution scanning. As the electronic components of the detector elements have been integrated directly into the photodiode, the electronic noise could be reduced by 20–30%. Thus the Signal-to-Noise-Ratio is significantly increased, allowing for a much better utilization of low signals, as is the case in pediatric studies, for instance. As cross-talk between neighboring detector elements is reduced, intrinsic slice blurring is avoided, leading to more precise individual slice profiles. In combination with Siemens' Edge Technology, which correctly models the focal spot and detector, a slice thickness of only 0.5 mm is achieved. Morsbach et al. were among the first to clinically evaluate the Stellar Detector. They found significantly reduced image noise and a higher accuracy when it came to stenosis grading: "Our ex vivo and patient study indicates significantly reduced image noise and more accurate stenosis quantification in coronary CT angiography when acquiring data using an IC (integrated circuit) detector."[16] Combined with the Edge Technology, the Stellar Detector provides a spatial resolution of up to 0.3 mm. As a result blooming is minimized thus reducing the rate of false positives – for enhanced vessel delineation and increased in-stent restenosis evaluation.

SOMATOM Definition Flash

Multiplanar reformat (MPR) of a stent without the Image Sharpening Tool.

Courtesy German Heart Center, Munich, Germany

SOMATOM Definition Flash

The same view with the Image Sharpening Tool activated. The sharper image allows for enhanced vessel delineation.

Image Sharpening for a thorough evaluation of calcified lesions and stents

Siemens' multi-modality client-server imaging platform *syngo*.via features several applications dedicated to specific clinical tasks. For the quantitative assessment of the coronary arteries, *syngo*.CT Coronary Analysis provides the Image Sharpening Tool. It directly converts an image reconstructed with a smooth B26 kernel to a B46 image without the need for additional reconstructions. However, the edge enhancement typical for the B46 image is maintained. Blooming artifacts are reduced for a thorough evaluation of calcified lesions or stents. As a non-obstructive vessel can now be distinguished more reliably from an actual occluded one, the rate of false positives is significantly lowered. Furthermore, this feature allows to save up to three minutes of extra reconstruction time at the scanner.

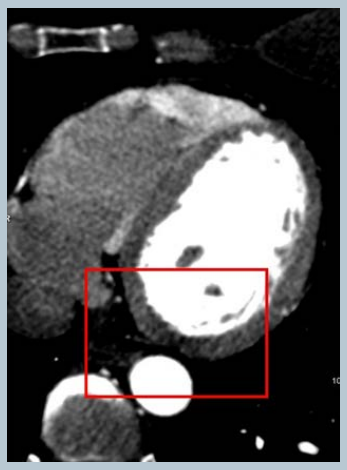
Available with the CT Cardio-Vascular Engine

Get specific in determining the hemodynamic relevance of a stenosis

Due to CT's high negative predictive value, it is possible to safely rule out CAD, thus reducing the need for cardiac catheterization. All features described enable highest diagnostic confidence in the assessment of calcified and non-calcified lesions. Given this optimal coronary evaluation one challenge remains – what to do with intermediate coronary lesions? Common practice is to refer the patient to other imaging tests in which a vasodilator is administered in order to simulate stress conditions. These tests are designed to answer whether the stenosis present is hemodynamically relevant. In recent years, CT has presented itself as a one-stop-shop, proving that it can also assess the hemodynamic relevance of a stenosis.[17, 18, 19, 20, 21, 22] It has been shown that combining cCTA with CTP boosts the specificity from 71% to 91%.[7]

In 2009, Siemens introduced a technique that allows to calculate quantitative values for myocardial blood flow and volume – parameters traditionally reserved for MRI. With this dynamic quantitative myocardial perfusion assessment Siemens is the industry's only manufacturer providing the full spectrum of myocardial perfusion analyses: be it straightforward single energy first pass enhancement imaging, Dual Energy Imaging for the quantitative assessment of iodine uptake in the myocardium, quantitative dynamic myocardial perfusion imaging or late enhancement imaging.

In order to make myocardial perfusion imaging with CT a reliable alternative to the standard approaches, such as SPECT, PET, or MRI, Siemens has introduced a strong portfolio of features to minimize false positive findings and to boost specificity also in perfusion imaging. Each approach to myocardial perfusion benefits from its own optimization feature designed to reduce the imaging challenges inherent to each approach.



SOMATOM Definition Flash without MBHC

The high contrast agent concentrations in the left ventricle and descending aorta cause a beam hardening artifact mimicking a perfusion defect.

SOMATOM Definition Flash with MBHC

After application of the Myocardial Beam Hardening Correction the true CT-values are restored.

Myocardial Beam Hardening Correction (MBHC) for reliable first pass enhancement scanning

In myocardial perfusion imaging using first pass enhancement one looks at the uptake of contrast agent in the myocardium. Decreased CT values hint at a possible perfusion defect. Exams under rest and under stress conditions help to determine whether a defect is reversible or not.[18] It has been shown, however, that high concentrations of iodine in the left ventricle and descending aorta cause beam hardening artifacts that also result in decreased CT values and may mimic a perfusion defect.[23] These beam hardening artifacts are a frequent cause of false positive findings in single energy first pass myocardial perfusion exams. As a solution to this problem Siemens has introduced a dedicated beam hardening correction which restores the CT values in the affected area to their true value – thus drastically reducing false positive findings.

Available on
SOMATOM Definition Flash
SOMATOM Definition Edge
SOMATOM Definition AS

SOMATOM Definition Flash

heart rate: 60 bpm

rotation time: 0.28 s

collimation: 64 x 0.6 mm

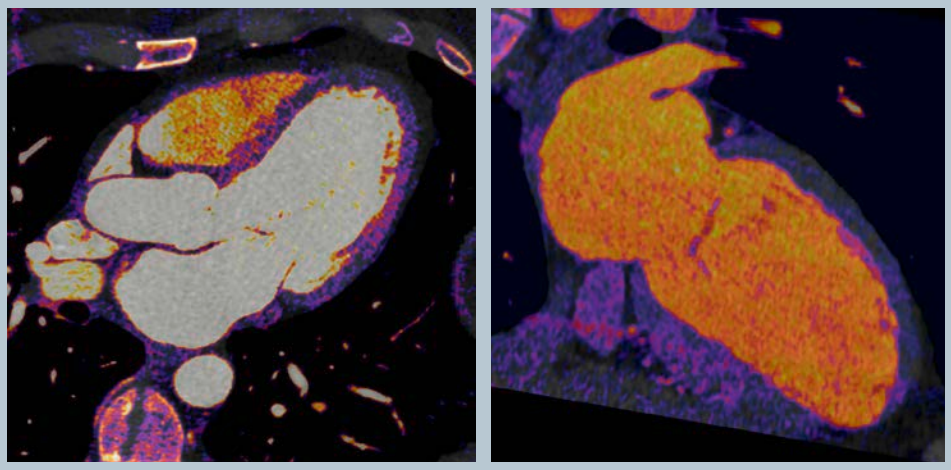
scan length: 134 mm

tube voltage: 100 kV / 140 kV

DLP : 408 mGycm

effective dose: 5.7 mSv

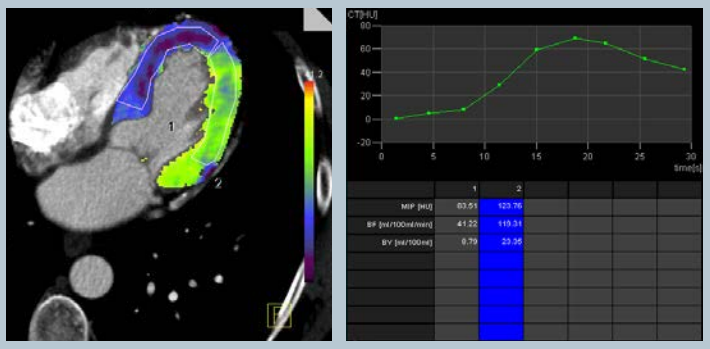
Courtesy Medical University of South Carolina, Charleston, USA

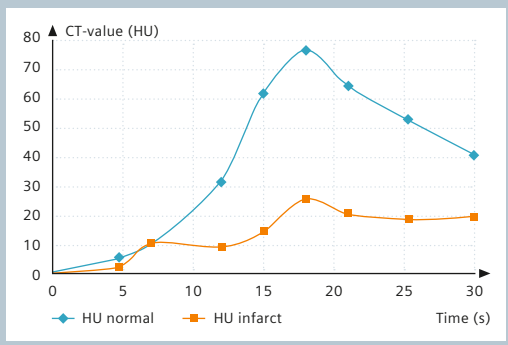


Available only on SOMATOM Definition Flash

Dose-neutral Cardiac Dual Energy without compromise

The concept of Dual Energy scanning has been around for decades.[24] With the introduction of the SOMATOM Definition, the world's first Dual Source CT scanner, this technology has made its way into clinical routine. Only with Dual Source CT, the patient can be scanned simultaneously at two different kV settings, which makes other clearly inferior approaches, such as rapid kV-switching or sandwich detectors, obsolete. The most challenging application of Dual Energy is cardiac imaging, as high temporal resolution is crucial here. For this task Siemens introduced a dedicated feature with the SOMATOM Definition Flash that allows you to maintain the optimum temporal resolution of 75 ms while at the same time acquiring Dual Energy data sets. This feature is superior to rapid kV-switching which only achieves temporal resolutions of up to 175 ms, has to halfen the number of projections per kV dataset (degrading image quality) and applies much higher dose since many dose reduction features are not available with this technique. Using DSCT 90° from each detector are combined to undergo a high pass filter. This first step extracts the sharp image details that require highest temporal resolution. In a second step the complimentary low pass part is taken from two regular 180° images at 80 kV and 140 kV. This low pass contribution provides the soft tissue information. Combining the two results in a cardiac image with 75 ms temporal resolution – extracted from a Dual Energy scan. This reduces false positive findings not only for cCTAs, but also for first-pass and late-enhancement perfusion imaging.[25, 22] Weininger et al. found a sensitivity of 93% and a specificity of 99% for the detection of myocardial perfusion defects.[21]





With quantitative dynamic myocardial perfusion values for blood flow and volume are obtained. The huge infarcted area shows a decreased blood flow as compared to healthy tissue. The corresponding time attenuation curves (right image) exhibit decreased peak enhancement and extended time to peak values.

SOMATOM Definition Flash

heart rate-independent temporal resolution: 75 ms

rotation time: 0.28 s

collimation: 32 x 1.2 mm

tube voltage: 100 kV

DLP: 587 mGycm

effective dose: 8.2 mSv

Courtesy Hospital Sirio Libanes, Sao Paulo, Brazil

Quantitative dynamic myocardial perfusion assessment

By introducing the first quantitative dynamic myocardial perfusion scan with the SOMATOM Definition Flash, Siemens revolutionized myocardial perfusion imaging. Over a time period of about 30 seconds, the Definition Flash measures the time attenuation curve (TAC) of the iodine uptake in the myocardium. Depending mainly on the patient's heart rate this implies roughly 15 prospectively triggered sequence scans. Prospectively triggered scanning keeps the dose low, totaling an effective dose of roughly 9 mSv.[20] The benefits of this scan mode may outweigh the increased dose compared to a simple single-shot first pass enhancement scan: the application of advanced algorithms yield absolute quantitative values on myocardial blood flow and volume.[26] Studies have shown that this approach is even more accurate than SPECT.[22] Bamberg et al. have found that the combination of quantitative dynamic perfusion measurements significantly increase the specificity when combined with a standard cCTA.[19] As the entire TAC is sampled the peak of the contrast agent uptake in the myocardium can be reliably and reproducibly determined. Therefore the dynamic scan mode is superior to a simple single-shot first pass enhance-ment scan, as variable scan timing may influence the appearance of a defect.[20] Furthermore, the high temporal resolution inherent to the SOMATOM Definition Flash allows for end-systolic triggering: The accurate assessment of myocardial perfusion benefits from a thicker, contracted myocardium and the reduced amount of contrast agent in the ventricle during that phase minimizes beam hardening artifacts – minimizing false positives in dynamic myocardial perfusion scanning.[23]

Available on SOMATOM Definition Flash

Scanner	Temporal resolution			Spatial resolution			Myocardial perfusion		
	Highest rotation speed	Dual Source CT	iTRIM	Edge-enhancing kernel	Stellar Detector	Image Sharpen-ing*	Beam Hardening Correction	75 ms Cardiac Dual Energy	Quantitative Dynamic Myocardial Perfusion
SOMATOM Perspective			●	●		●			
SOMATOM Definition AS	●			●		●	●		
SOMATOM Definition Edge	●			●	●	●	●		
SOMATOM Definition Flash	●	●		●	●	●	●	●	●

* Optional with *syngo*.via

Get specific with your personal needs

Anticipating institutions' versatile clinical and financial requirements Siemens offers a broad range of suitable CT scanners: Starting with the SOMATOM Perspective to the SOMATOM Definition Flash representing the gold standard in motion-free coronary imaging. Unique to each scanner is the combination of features to minimize false positive findings.

On top of that the CT Cardio-Vascular Engine represents a fine-tuned bundle combining these innovative scanner technologies with advanced software applications to speed up routine tasks such as rule-out of coronary heart disease. The highly automated evaluation tools help to accelerate the anatomical evaluation, quantification, and functional assessment of CT angiography images while offering full control to adjust the results in challenging cases.

Literature

[1] Litt HI, et al. CT angiography for safe discharge of patients with possible acute coronary syndromes. N Engl J Med. 2012 Apr 12; 366(15):1393-403.

[2] Achenbach S, et al. Detection of coronary artery stenoses by low-dose, prospectively ECG-triggered, high-pitch spiral coronary CT angiography. JACC Cardiovasc Imaging. 2011 Apr; 4(4):328-37.

[3] Budoff MJ, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. J Am Coll Cardiol 2008; 52:1724 –32.

[4] Meijboom WB, et al. Diagnostic accuracy of 64-slice computed tomography coronary angiography: a prospective, multicenter, multivendor study. J Am Coll Cardiol 2008; 52:2135– 44.

[5] Paech DC, et al. A systematic review of the clinical effectiveness of 64-slice or higher computed tomography angiography as an alternative to invasive coronary angiography in the investigation of suspected coronary artery disease. BMC Cardiovasc Disord. 2011 Jun;11:32.

[6] Raff G, et al. Diagnostic accuracy of noninvasive coronary angiography using 64-slice spiral computed tomography. J Am Coll Cardiol. 2005; 46:552-557.

[7] Rocha-Filho JA, et al. Incremental Value of Adenosine induced Stress Myocardial Perfusion Imaging with Dual-Source CT at Cardiac CT Angiography. Radiology. 2010; 254(2): 410-9.

[8] Donnino R, et al. Dual-source versus single-source cardiac CT angiography: comparison of diagnostic image quality. AJR Am J Roentgenol. 2009 Apr; 192(4):1051-6.

[9] Alkadhi H, et al. Dual-source computed tomography coronary angiography: influence of obesity, calcium load, and heart rate on diagnostic accuracy. Eur Heart J. 2008 Mar; 29(6):766-76.

[10] Scheffel H, et al. Low-dose CT coronary angiography in the step-and-shoot mode: diagnostic performance. Heart. 2008 Sep; 94(9):1132-7.

[11] Johnson TR, et al. Diagnostic accuracy of dual-source computed tomography in the diagnosis of coronary artery disease. Invest Radiol. 2007 Oct; 42(10):684-91.

[12] Baumüller S, et al. Dual-source versus 64-section CT coronary angiography at lower heart rates: comparison of accuracy and radiation dose. Radiology. 2009 Oct; 253(1):56-64.

[13] Achenbach S, et al. Influence of heart rate on the accuracy of dual source CT for coronary stenosis detection in patients with intermediate likelihood of disease: results of the international multicenter MEDIC trial. European Heart Journal (2012) 33 (Abstract Supplement), 93.

[14] Schöndube H, et al. Evaluation of a novel CT image reconstruction algorithm with enhanced temporal resolution. Proc. SPIE. 2011; 7961, 79611N.

[15] Seifarth H, et al. Assessment of coronary artery stents using 16-slice MDCT angiography: evaluation of a dedicated reconstruction kernel and a noise reduction filter. Eur Radiol. 2005 Apr; 15(4):721-6.

[16] Morsbach F, et al. Stenosis Quantification in Coronary CT Angiography – Impact of an Integrated Circuit Detector With Iterative Reconstruction. Invest Radiol. 2013 Jan; 48(1):32-40.

[17] Blankstein R, et al. Adenosine-induced stress myocardial perfusion imaging using dual-source cardiac computed tomography. JACC 2009 Sep 15; 54(12):1072-84.

[18] Feuchtner G, et al. Adenosine Stress High-pitch 128-slice Dual Source Myocardial Computed Tomography Perfusion For Imaging Of Reversible Myocardial Ischemia: Comparison with Magnetic Resonance Imaging. Circ Cardiovasc Imaging. 2011 Sep; 4(5):540-9.

[19] Bamberg F, et al. Detection of hemodynamically significant coronary artery stenosis: incremental diagnostic value of dynamic CT-based myocardial perfusion imaging. Radiology. 2011 Sep; 260(3):689-98.

[20] Ho KT, et al. Stress and Rest Dynamic Myocardial Perfusion Imaging by Evaluation of Complete Time-Attenuation Curves With Dual-Source CT. JACC. 2010; 3(8): 811-820.

[21] Hamilton-Craig C, et al. Myocardial Viability by Dual-Energy Delayed Enhancement Computed Tomography. JACC. 2011; 4(2):207-208.

[22] Weininger M, et al. Adenosine-stress dynamic real-time myocardial perfusion CT and adenosine-stress first-pass dual-energy myocardial perfusion CT for the assessment of acute chest pain: Initial results. Eur J Radiol. 2010 Dec 29.

[23] Stenner P, et al. Dynamic iterative beam hardening correction (DIBHC) in myocardial perfusion imaging using contrast-enhanced computed tomography. Invest Radiol. 2010 Jun; 45(6):314-23.

[24] Alvarez R, Macovski A. Energy-selective reconstructions in x-ray CT. Phys. Med. Biol. 1976; 21, 733–744.

[25] Nance JW, et al. High-Temporal Resolution Dual-Energy Computed Tomography of the Heart Using a Novel Hybrid Image Reconstruction Algorithm: Initial Experience. J Comput Assist Tomogr. 2011; 35(1):119-25.

[26] Mahnken AH, et al. Quantitative whole heart stress perfusion CT imaging as noninvasive assessment of hemodynamics in coronary artery stenosis: preliminary animal experience. Invest Radiol. 2010 Jun; 45(6):298-305.

In the event that upgrades require FDA clearance, Siemens cannot predict whether or when the FDA will issue its clearance. Therefore, if regulatory clearance is obtained and is applicable to this package, it will be made available according to the terms of this offer.

On account of certain regional limitations of sales rights and service availability, we cannot guarantee that all products included in this brochure are available through the Siemens sales organization worldwide. Availability and packaging may vary by country and are subject to change without prior notice. Some/All of the features and products described herein may not be available in the United States.

The information in this document contains general technical descriptions of specifications and options as well as standard and optional features which do not always have to be present in individual cases.

Siemens reserves the right to modify the design, packaging, specifications, and options described herein without prior notice. Please contact your local Siemens sales representative for the most current information.

Note: Any technical data contained in this document may vary within defined tolerances. Original images always lose a certain amount of detail when reproduced.

Please find fitting accessories:
www.siemens.com/medical-accessories

Global Business Unit
Siemens AG
Medical Solutions
Computed Tomography &
Radiation Oncology
Siemensstr. 1
DE-91301 Forchheim
Germany
Phone: +49 9191 18 0
Fax: +49 9191 18 9998

Global Siemens Headquarters
Siemens AG
Wittelsbacherplatz 2
80333 Muenchen
Germany

Global Siemens Healthcare Headquarters
Siemens AG
Healthcare Sector
Henkestrasse 127
91052 Erlangen
Germany
Phone: +49 9131 84-0
www.siemens.com/healthcare

Legal Manufacturer
Siemens AG
Wittelsbacherplatz 2
DE-80333 Muenchen
Germany

Order No. A91CT-12019-60C1-7400 | Printed in Germany | CC 959 05130.1 | © 05.2013, Siemens AG

www.siemens.com/healthcare