Coronary CTA
Image Acquisition and Interpretation
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Abstract: Computed tomography (CT) of the heart, because of ongoing technical refinement and intense scientific and clinical evaluation, has left the research realm and has matured into a clinical application that is about to fulfill its promise to replace invasive cardiac catheterization in some patient populations. By nature of its target, the continuously moving heart, CT coronary angiography is technically more challenging than other CT applications. Also, rapid technical development requires constant adaptation of acquisition protocols. Those challenges, however, are in no way insurmountable for users with knowledge of general CT technique. The intent of this communication is to provide for those interested in and involved with coronary CT angiography a step-by-step manual, introducing our approach to performing coronary CT angiography. Included are considerations regarding appropriate patient selection, patient medication, radiation protection, contrast enhancement, acquisition and reconstruction parameters, image display and analysis techniques and also the radiology report. Our recommendations are based on our experience which spans the evolution of multidetector-row CT for cardiac applications from its beginnings to the most current iterations of advanced acquisition modalities, which we believe herald the entrance of this test into routine clinical practice.

Key Words: coronary CTA, multidetector-row CT

With the ongoing evolution of ever faster and more sophisticated multidetector-row computed tomography (MDCT) technology, CT of the heart has evolved into an examination that is applied to a broad variety of clinical indications.1 With the advent of the latest iterations of MDCT technology, both temporal and spatial resolution of coronary CT angiography (CTA) have improved to a point where the threshold to routine noninvasive assessment of the coronary arteries for atherosclerotic disease may have been crossed.

Imaging of the heart has always been technically challenging, because of the heart’s continuous motion. The development of electrocardiography (ECG)-synchronized MDCT scanning and reconstruction techniques2–4 has provided fast volume coverage and high spatial and temporal resolution as a prerequisite for successful cardiac imaging.5 The exceedingly powerful technology which enables performance of coronary CTA, however, transcends routine CT applications and needs to be used in a manner to provide optimized results with the least degree of invasiveness for the patient. Our experience performing contrast enhanced coronary CTA has evolved over the years since the introduction of MDCT and has encompassed every single evolutionary step of this technology up to the most current generation of dual-source CT (DSCT). The purpose of this communication is to share our experience with those interested in and involved with coronary CTA to facilitate the beneficial application of this procedure.

PATIENT PREPARATION

IV Access
Intravenous access is preferably established in a cubital vein. Especially, if a left internal mammary arterial bypass graft is to be assessed, an access site in the right arm should be chosen to prevent streak artifacts arising from dense contrast material in the left subclavian vein from interfering with the evaluation of left internal mammary arterial origin. Because of the fairly fast injection rates of 4 to 5 mL/s, an 18-G catheter or larger should be used, whenever possible.

ECG Lead Attachment
Ordinarily, a 3-lead ECG is used for cardiac CT. A stable reading of the patient’s ECG with clear identification of the QRS-Complex is a prerequisite for successful retrospective ECG-gating. To establish good electrical contact and prevent lead detachment with consecutive signal loss during scan acquisition, use of additional conductive gel and shaving of overly hairy attachment sites are recommended.
Rate Control

Rate Control for Improving Image Quality

For a variety of reasons, slow heart rates are highly desirable for cardiac CT using 4-slice to 64-slice scanners: Slow heart rates relatively prolong the cardiac phases with little cardiac motion, that is, end-diastolic relaxation and end-systolic contraction, so that a reconstruction interval of a defined duration can be safely placed within these phases without inclusion of preceding or consecutive portions of the heart cycle that contain motion.

In our practice, we aim at a target heart rate of between 50 and 65 beats per minute (bpm) for our 64-slice CT scanners. With DSCT, the newest scanner generation, heart rate control might not be necessary anymore. In our experience, DSCT allows scanning patients with high (ie, 120 to 140 bpm) and irregular heart rates with diagnostic results (Fig. 1). These scanners employ 2 x-ray sources and 2 corresponding detectors offset by 90 degrees, thus providing a temporal resolution equivalent to a quarter of the gantry rotation time (ie, 83 ms), independent of the patient’s heart rate.6

Rate Control for Single-segment Reconstruction in Single-source CT Scanners

As a direct consequence of this high temporal resolution, image reconstruction can be ordinarily performed using single-segment reconstruction, that is, based on the projections that are acquired during a single heartbeat. Single-segment reconstruction has theoretical advantages over multisegment reconstruction algorithms that are implemented on all available cardiac CT scanners. At multisegment reconstruction, the projections that are needed to form a single section are sampled over 2 to 4 consecutive heart beats.5 Although this approach improves temporal resolution, which is beneficial for faster heart rates, it requires that the heart follows the exact same motion pattern for each of the 2 to 4 heart beats during which projection sampling for reconstruction of a single section occurs. This, however, is unreasonable to expect, given the variability of cardiac motion patterns even under physiologic conditions so that spatial inconsistencies within the data inevitably occur with the use of multisegment reconstruction. In our practice, we strive to avoid the use of multisegment reconstruction algorithms by appropriately reducing the heart rate with 64-slice CT and use it exclusively in patients with heart rates >80 bpm, above which, in our experience, the benefits of improved temporal resolution outweigh the risk of spatial inconsistency.

Rate Control for Radiation Protection

Up to the generation of 64-slice CT, rate control has been directly related to patient radiation exposure at cardiac CT. Significant dose savings can be realized with ECG-gated dose-modulation (“ECG-pulsing”).5,7 With this approach, the nominal tube output is only applied

FIGURE 1. Contrast enhanced, retrospectively ECG-gated dual-source coronary CTA in a 62-year-old man with persistent atrial fibrillation and tachyarhythmia after pulmonary vein ablation therapy. The heart rate during the CT scan varied between 67 and 150 bpm (A). Despite this high and irregular heart rate, the stable temporal resolution of 83 msec enabled by this technology resulted in a data set of sufficient diagnostic quality. Volume rendered displays both, during diastole (B) and systole (C) are of comparable image quality and do not show motion or misregistration artifacts.
During the particular phase of the cardiac cycle at which images are most likely to be reconstructed. Over the rest of the cardiac cycle, the tube output is reduced. However, the use of ECG-gated dose-modulation is limited to patients with slow and steady heart rates, in whom the optimal time-point for image reconstruction predictably occurs during diastole (Fig. 2). At faster heart rates, ECG-gated dose-modulation increasingly loses its efficacy, as the period of reduced tube output becomes progressively shorter relative to the cardiac cycle. More importantly, with faster heart rates, the optimal time-point for image reconstruction becomes more difficult to predict and, in the case of 64-slice CT frequently occurs during the end-systolic phase of total myocardial contraction (Fig. 3). Because with ECG-gated dose-modulation the radiation level is typically reduced during systole, diagnostic quality will inevitably be compromised during image reconstruction so that use of ECG-gated dose-modulation is not recommendable for faster heart rates. This way, rate control has become a crucial factor in the endeavor of keeping radiation exposure at cardiac CT within reasonable limits. In our practice, with 64-slice CT, we used ECG-gated dose-modulation in patients with steady heart rates < 65 bpm. We feel that in patients with faster and more irregular heart rates ECG-gated dose-modulation limits, our options with regard to the selection of the optimal reconstruction time-point too much as to recommend its general use.

These rules do not apply for the use of DSCT. Because of a temporal resolution window of only 83 ms, ECG dose-modulation can be applied much more effectively. Full energy windows covering only a 10% window of the cardiac cycle are feasible. Additionally, DSCT allows the adaptation of the pitch to the patient’s heart rate, because multisegment reconstruction for higher heart rates will not be required. The table feed can be efficiently adapted to the patient’s heart rate and significantly increased at faster heart rates. As shown by McCollough et al., this may reduce radiation dose in cardiac CT by up to 50% compared with single-source CT.

Rate Control: Practical Aspects

In our practice, we routinely used intravenous β-blocker (Metoprolol Tartrate, Lopressor, Novartis, East Hanover, NJ) for controlling our patients’ heart rate with very satisfactory results and without complications to date. Contraindications for the use of β-blockers include chronic obstructive pulmonary disease, asthma, sensitive to β-agonists, second-degree or third-degree heart block; hypotension (< 100 mm Hg systolic). In the absence of contraindications, we inject an initial bolus of 5 mg of Metoprolol while the patient is already on the scanner table and preparations for scanning ensue. If the ventricular response is unsatisfactory, that is, the average heart rate remains > 70 bpm, we inject up to 2 additional doses (15 mg total maximum) of Metoprolol. After administration of 3 doses, we commence scanning, regardless of the heart rate that is eventually achieved after β-blocker administration. Oral administration of β-blockers is an alternative means of rate control, which compared with our intravenous protocol, exerts higher demands on operational logistics. If oral administration is preferred, ideally, the regimen should be commenced the night before the scan with an initial dose of 50 to 100 mg of Metoprolol. Thirty to sixty minutes before the scan,
another dose is given, followed by a third dose in the absence of adequate ventricular response. There is less experience with alternative rate-controlling medications. However, if there are contraindications for use of β-agonists (see above), an attempt with calcium channel blockers may be worthwhile. Calcium channel blockers can be administered either intravenously [0.25 mg/kg bodyweight (up to 25 mg total) Diltiazem, Cardizem Monovial, Hoechst Marion Roussel, Kansas City, MO] or as an oral regimen with 30 mg of regular release Diltiazem (Cardizem, Biovail, Toronto, Canada). In our practice, all patients who receive rate-controlling medications or nitroglycerin (NTG) (see below) are monitored for 30 minutes after administration of the last dose.
pressure measurements are performed before administration of the drug and before discharge. Patients who receive more than 1 dose of β-blockers are instructed not to drive or operate machinery for 3 hours after the administration of the drug.

**NTG**

No systematic studies are available to support the use of NTG in the context of cardiac CT. In patients referred for coronary CTA for suspected coronary artery disease, we administer a 0.4 mg NTG tablet (NitroQuick, Ethex, St Louis, MO) sublingually 2 minutes before the scan with the theoretical rationale of widening the coronaries for better visualization and suppressing coronary artery spasms that may mimic stenosis at coronary CTA especially in younger individuals. Sublingual spray can be used alternatively. Contraindications for NTG comprise hypotension, early myocardial infarction, severe anemia, increased intracranial pressure, and known hypersensitivity to NTG. We also do not give NTG to patients who recently took nitrate-based medication (Viagra, Cialis, Levitra) for erectile dysfunction.

**SCANNING PARAMETERS**

**Gantry Rotation Speed and Collimated Section Width**

At coronary CTA, the target anatomy is minute, tortuous, and moving rapidly. Accordingly, as a universal rule that applies to MDCT scanners of all manufacturers, for optimally performing coronary CTA one can never slice too thin or spin too fast. Thus, at coronary CTA, regardless of the scanner type used, the thinnest possible collimation and the fastest gantry rotation time should be chosen. An exception is the rare situation where the patient’s heart rate is so slow (typically < 50 bpm), that use of a somewhat slower gantry rotation with slower pitch is required to avoid gaps in the acquired data set.9 Another scenario where choice of a somewhat slower gantry rotation speed may be considered is the severely obese patient, where slower gantry rotation may be helpful to enhance the photon flux and improve the signal-to-noise ratio at coronary CTA. DSCT, with its 2 x-ray tubes, is considerably better suited than single-source CT for suppressing image noise in obese patients. A reduction in gantry rotation speed with this latter technology is generally not necessary. Rather, a heart rate range can be selected that is lower than the patient’s actual heart rate which results in an artificially lower table speed and accumulation of dose to suppress image noise.

**Tube Current and Voltage**

Issuing general recommendations for the selection of tube current settings is challenging, as the appropriate tube current level depends on several scanner specific variables, such as the collimated section width and the gantry rotation speed. As with all CT applications, the ALARA (As Low As Reasonably Achievable) principle applies, that calls for patient specific adjustment of the scanner settings to the patient’s body habitus so that the lowest possible tube current setting is chosen that still results in a diagnostic study. When scanning normal sized adults for suspected coronary artery disease with 0.6 mm collimation and 330 msec gantry rotation, we ordinarily adjust the tube current to 750 to 800 mAs eff w with single-source CT, always employing all means available for reducing radiation exposure to the patient (ie, ECG-pulsing, see above). With DSCT, scanning parameters of 120 kV per tube with a current of 560 mA and the use of anatomic tube current modulation is ordinarily chosen. The gantry rotation time is usually set to 0.330 seconds and the pitch ranges from 0.2 to 0.43 depending on heart rate.

As the x-ray absorption of iodine is inversely proportional to the tube potential, very high tube voltage settings (ie, 140 kV) are generally not recommendable for contrast enhanced CTA. When scanning normal sized or larger adults for suspected coronary artery disease, we ordinarily employ a tube potential of 120 kV. Substantial dose savings can be realized by lowering the tube voltage to 100 or 80 kV, while the level of vascular attenuation increases. Thus, in slim adults the tube voltage can be safely lowered to 100 kV with very satisfactory results in our experience. Similarly, depending on the size of the patient, we routinely use 100 or 80 kV, when performing cardiac CT in adolescent or pediatric patients for suspected coronary artery anomalies or other congenital cardiovascular disorders.10

**CONTRAST ENHANCEMENT**

**Level of Enhancement**

High and consistent vascular enhancement within the vessel lumen is a prerequisite for successful coronary CTA. Adequate enhancement is needed for visualization of the vessel wall, of small side branches of the coronary tree and, especially in obese patients, to compensate for increased levels of image noise that limit contrast resolution at thin-section coronary CTA. In addition, high and homogenous enhancement serves as the basis for threshold-dependent 3-dimensional visualization techniques. To achieve the desired high vascular enhancement, we use high concentration 350 to 370 mgI/mL nonionic contrast media with a fast injection rate of 5 to 6 mL/s. It has been argued that exceedingly high intraluminal contrast may interfere with the detection of calcified atherosclerotic plaque. In our experience, this pitfall can be easily avoided by appropriately adjusting window center and width (C ≈ 100 HU; W ≈ 700 HU) according to the level of enhancement that was achieved in the individual patient.

**Saline Chasing Technique**

Significant scientific effort is currently directed at understanding and optimizing contrast dynamics at CTA.11,12 Insights gained from ongoing investigations are continuously implemented in commercially available automated injectors. One such implementation that has
become imperative for coronary CTA is the use of a saline chaser enabled by dual-syringe injection systems. Use of a saline chaser aims at better utilization of the injected contrast media by prolonging the plateau-phase of contrast. More importantly, use of a saline chaser reduces the occurrence of streak artifact from dense contrast media in the superior vena cava and the right heart chambers. At coronary CTA, such streak artifacts have the potential to significantly limit the evaluation of the right coronary artery (RCA), and may simulate stenosis especially at 2-dimensional and 3-dimensional image postprocessing (Fig. 4). However, the occurrence of streak artifacts may be reduced or entirely avoided, if at the time of image acquisition the contrast material is flushed from the right heart by use of saline chaser technique. On the other hand, a complete void of contrast

**FIGURE 4.** Contrast enhanced, retrospectively ECG-gated CT coronary angiography without saline chasing technique. Display as transverse section (A) and volume rendering (B), seen from a left anterior oblique perspective. A streak artifact emanating from dense contrast material in the right heart (arrow in A) overlies the RCA and causes artifactual stenosis (arrow in B) of the proximal RCA.
in the right heart is undesirable, as right heart analysis is precluded. We aim at improving right heart visualization by using the 3 phases of injection where the initial iodine bolus is followed by a saline/contrast mixture enabled by simultaneous injection from both syringes (Dual Flow Technology, Medrad, Pittsburgh, PA) and a final saline chaser (see below). This strategy provides sufficient enhancement for assessment of the right heart (Fig. 5) for detection of thrombo-emboli, tumors, etc, while streak artifacts from dense contrast material can generally be avoided.

**Contrast Protocol**

In our practice, the individual delay time is determined by injection of a 20 mL contrast media test bolus at 5 mL/s (64-slice CT) or 6 mL/s (DSCT), followed by 50 mL of saline using a dual-syringe injector (Stellant D, Medrad). Repeated scanning at the same z-position at the level of the aortic root is performed to monitor the arrival and passage of the test bolus. The peak time of test bolus enhancement is used as the delay time. The contrast volume for the actual coronary CTA scan is individually computed according to the following formula: Volume (mL) = scan time (s) × 5 (64-slice CT) or × 6 (DSCT). The injector is preprogrammed to deliver 50 mL of a 30% contrast media/70% saline mixture during the second phase of injection, followed by a final 30 to 50 mL saline chaser, all injected at 5 mL/s (64-slice CT) or 6 mL/s (DSCT), respectively.

**IMAGE RECONSTRUCTION**

### Single-segment Versus Multisegment Reconstruction Algorithms

For considerations regarding use of single-segment versus multisegment reconstruction, please see above discussion on rate control (“Rate Control for Single-Segment Reconstruction with Single Source CT Scanners” section). In general, we avoid the use of multisegment reconstruction in patients with heart rates of less than 80 bpm with 64-slice CT and entirely with DSCT.

### Choosing the Optimal Reconstruction Interval

For the assessment of cardiac morphology, a phase with minimal cardiac motion is preferably chosen for placement of the image reconstruction interval. To define the starting point of the reconstruction interval within the cardiac cycle, absolute and relative approaches are available on most cardiac CT scanner types. With an absolute approach, each image reconstruction interval is placed in the cardiac cycle with a predefined temporal distance (eg, 400 ms) before or after an R-peak in the ECG. With a relative approach, the starting point of the image reconstruction interval is defined as a certain percentage (eg, 60%) of the duration of the cardiac cycle. We use the relative, percentage-based approach for 64-slice CT and an absolute approach for DSCT. If available, a preview function is preferably used for determining the optimal reconstruction phase with the least cardiac motion. Typically, the preview series consists

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**FIGURE 5.** Contrast enhanced, retrospectively ECG-gated CT coronary angiography in 3 different patients. Use of a monophasic injection (left) of iodine only, using a single syringe injector, results in dense streak artifacts in the right heart. Use of a biphasic injection (middle) with a dual-syringe injector and saline chasing technique flushes residual contrast from the right heart and avoids artifacts; however, the right cardiac chambers can no longer be assessed. A triphasic injection, also using a dual-syringe injector, with simultaneous flow (right) from 2 syringes administers a mixture of contrast and saline during the second injection phase. This provides sufficient enhancement for assessment of the right heart while streak artifacts from dense contrast material can generally be avoided.
of 20 images (Fig. 6), reconstructed at 20 different RR positions in 5% increments (0% to 95% RR) at the same z-position at the mid-level of the heart. The phase that shows the least motion artifacts in both, the left and RCA system is chosen for the image reconstruction. In cases where the right and left coronary artery show diverging motion patterns, more than one reconstruction is performed for optimized visualization of both arterial systems. If a preview function is not available, a first image reconstruction of the data set can be performed at 60% RR (Fig. 2), which has been shown to result in diagnostic image quality in most patients, especially at slower, regular heart rates. With the improved temporal resolution of newer scanners, late systole with total cardiac contraction (ie, 30% to 40% RR) has emerged as a second suitable time-point for image reconstruction (Fig. 3), where cardiac motion is at a minimum. In our experience, image reconstruction during late systole yields diagnostic results in most patients with a faster heart rate and is especially well suited for visualization of the RCA.

**Reconstruction Parameters**

**Field of View**

To maximize spatial resolution, the smallest possible field of view should be chosen that encompasses the entire anatomy of the heart, for performing image reconstruction at CT coronary angiography. In addition, for each coronary CTA study, we perform a full field of view reconstruction of the entire chest along the acquired z-volume with 3-mm section thickness and a lung algorithm, to assess for incidental lung pathology. For specialized applications, such as “triple rule-out” scanning, we perform the 2 reconstructions described above and a third reconstruction with 1-mm section thickness, a vascular algorithm and a field of view that encompasses the entire chest, to evaluate for vascular pathology of the pulmonary circulation and the thoracic aorta.

**Section Thickness**

Generally, to avoid artifacts, thin-section MDCT data should be reconstructed with a section width that is
slightly wider than the collimated section width. For example, if the scan was acquired with 0.6-mm collimated section width, the next higher available reconstruction thickness (eg, 0.75 mm) should be chosen for the image reconstruction. Forty to sixty percent increment is ordinarily used for the image reconstruction at coronary CTA, which in our experience results in a somewhat crisper and sharper delineation of the coronary artery tree but does not necessarily improve diagnostic accuracy compared to contiguous image reconstruction without overlap.

Reconstruction Algorithm (“Kernel”)

Most CT scanners used for coronary CTA offer a dedicated reconstruction filter (kernel) for the image reconstruction of cardiac CT studies. Typically, these kernels maintain a degree of edge enhancement, to provide the spatial resolution necessary to visualize small vascular detail. Ideally, the kernels are also optimized to suppress image noise as much as possible, to improve the visual impression and maintain contrast resolution for evaluation of the myocardium and the vessel wall. For the evaluation of coronary artery stents, it is recommendable to use a kernel with even stronger edge enhancing characteristics and greater spatial resolution. This approach suppresses beam hardening artifacts to some extent and provides better delineation of metallic stent struts (Fig. 7) than the algorithms which are routinely used at coronary CTA. This approach may also somewhat increase the diagnostic yield in the presence of heavy calcifications, which pose a similar problem as dense stent struts for the evaluating luminal integrity. Although dedicated reconstruction algorithms improve visualization of coronary artery stents, our ability to assess for stent patency with CT is extremely variable and depends on the overall quality of the data set and the size and material of the stent. Because of this variability, reliable assessment of stents cannot be expected on a routine basis and we discourage use of CT for dedicated stent follow-up.

FIGURE 7. Contrast enhanced, retrospectively ECG-gated 64-slice coronary CTA in a 27-year-old woman status postmyocardial infarction and subsequent LAD stent placement referred for noninvasive disease surveillance because of desired pregnancy. Three-dimensional volume rendered display of the entire cardiac volume (A) and of the automatically extracted coronary artery tree (B) show the location of the stent (arrow) in the proximal LAD. Reconstruction of the same data set with a routine coronary CTA algorithm (C) and a more edge enhancing algorithm (D) dedicated to the assessment of coronary artery stents and segments with dense calcification. Display of the LAD as curved MPR (C, D) show the stent (arrow) in the proximal portion of the vessel. The dedicated stent reconstruction algorithm (D) enables somewhat more detailed assessment of the metallic stent struts and the patent lumen, particularly in the more distal portion of the stent.
For cardiac applications, the role of advanced, dedicated image display, and analysis tools is considerably greater than for general CT applications. Review of the individual transverse source images, however, cannot be abandoned and must be a part of the diagnostic process in each case. The transverse source images are richest in information regarding incidental mediastinal findings, artifacts (Fig. 4), and the overall atherosclerotic plaque burden within the coronary artery tree. Every postprocessing step necessarily and by design reduces the available information for the sake of more intuitive image visualization.

Depending on the particular indication for performing cardiac CT, we employ slightly different strategies for our diagnostic approach. When assessing bypass grafts or the left atrium and pulmonary veins in the context of ablation therapy for cardiac arrhythmia, a 3-dimensional volume rendered model is used for quick initial orientation, for example regarding the type and course of bypass grafts or the general configuration of the pulmonary venous return. This is followed by the review of transverse source images for the detection and grading of graft lesions or pulmonary vein stenosis and also additional or alternative findings in the chest. For suspected coronary artery stenosis, the transverse source images are initially reviewed, to obtain general information on the presence, location, and composition (calcified vs. noncalcified) of atherosclerotic lesions and also consequences of ischemic disease, such as myocardial perfusion deficits or scarring (Fig. 8). Once lesions are detected, stenosis severity is evaluated by using simple visualization tools that enable a more comprehensive, condensed display of the data set. Multiplanar reformats (MPRs, see below) are easy to use basic tools and are available on most CT scanners. For improved detection and grading of coronary artery lesions, we use dedicated visualization and analysis tools (see below), whenever interpreting a scan performed for suspected stenotic disease. Different from the evaluation of bypass grafts and pulmonary veins, there is a little diagnostic value in performing 3-dimensional volume rendered displays for suspected coronary artery disease, as lesions are frequently obscured or overestimated, depending on the rendering parameters. In our practice, 3-dimensional rendering is exclusively used for intuitive communication of our findings to referring physicians and patients.

MPRs
For visualization of the coronary artery tree at contrast enhanced CT coronary angiography, MPRs are widely used and recommended as a robust and easy to perform secondary visualization tool for data viewing. Because of the isotropic (equal voxel dimensions in x-axis, y-axis and z-axis) or near isotropic nature of
high-resolution CT acquisitions, image data can be rearranged in arbitrary imaging planes with comparable image quality as in the original transverse section.

MPRs serve the purpose of enabling views of coronary artery lesions from different angles and perspectives, which enables better assessment of stenosis severity and residual perfused lumen than can be appreciated by only a single projection. This is of particular importance in the presence of severe calcifications, where a single view often fails to display residual lumen in the vicinity of a heavily calcified plaque (Fig. 9).

**Advanced Visualization Tools**

Advanced software tools have become available and are being continuously refined that facilitate viewing and analysis of large volume data sets. The common rationale

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**FIGURE 9.** Contrast enhanced, retrospectively ECG-gated dual-source CTA in a 72 year old woman with atypical chest pain. Same patient as in Figure 6. The axial source images (left in A) and the sagittal MPR (middle in A) clearly demonstrate a moderate ostial stenosis (arrow) of the RCA, adjacent to dense calcifications in the right coronary sinus of the aorta. The lesion is more difficult to detect in the coronal reformat (right in A). Display as automatically generated curved MPR (B) is best suited for stenosis detection and grading, whereas display as 3-dimensional volume rendering (C) fails to show the full extent of the lesion.
of most of these software platforms is to provide a means for rapid analysis of the coronary artery tree for the detection and grading of stenosis. Typically, the first step of postprocessing after review of the transverse sections and MPRs (Fig. 10A) consists in automated sculpting of the chest wall to enable an unobstructed view of the heart (Fig. 9B). Threshold-dependent or contour-dependent extraction of the coronary arteries from the contrast enhanced data set is then performed (Fig. 10C). Most software applications enable unraveling of the tortuous course of the extracted coronary artery, which affords intuitive visualization of the entire vessel and the circumscribed lesion. Automated assessment of stenosis severity (E) at the level of the lesion shows 78% luminal obstruction (diameter measurement). Catheter angiography (F) later confirms the site and severity of the LAD lesion (arrow).

FIGURE 10. Contrast enhanced, retrospectively ECG-gated 64-slice coronary CTA in a 59-year-old man with atypical chest pain. Illustrated is the workflow of coronary CTA analysis, using dedicated visualization platforms. A circumscribed, short segment high degree stenosis (arrow) in the proximal LAD is difficult to detect on transverse, sagittal, or coronal MPRs (A). Postprocessing consists in automated sculpting of the chest wall to enable an unobstructed view of the heart (B), displayed as volume rendering. Automated extraction of the coronary arteries from the contrast enhanced data set is performed (C). The extracted coronary artery is displayed as an automatically generated MPR (D), which affords intuitive visualization of the entire vessel and the circumscribed lesion. Automated assessment of stenosis severity (E) at the level of the lesion shows 78% luminal obstruction (diameter measurement). Catheter angiography (F) later confirms the site and severity of the LAD lesion (arrow).

THE REPORT

We use a standardized template for reporting findings at coronary CTA. With the exception of a more detailed discussion of the coronary arteries and other cardiac structures, our coronary CTA reports are not fundamentally different from general radiology reports and include all pathology, variations, and changes that are visible on the different reconstruction series. In the Procedure section, we include the items that are pertinent to appropriate billing in our local health care environment. These items may be different in other geographical areas, but generally include the section thickness, use of retrospective ECG-gating, contrast volume and injection speed, medications used, and image postprocessing methods, such as MPRs or 3-dimensional reconstructions. In the Findings section, we begin with describing general cardiac and great vessel anatomy, commenting on the myocardium (thickness, areas of infarction, scars etc), the cardiac chambers, valves, pericardium, pulmonary veins, pulmonary arteries, and aorta. A section is dedicated to incidental findings in the chest wall, mediastinum, and lung, for example, the description and classification of lung nodules including recommendations for the follow-up according to standard clinical practice.17 In the cardiac section, we report on the
presence and location of cardiac devices, catheters etc. When coronary artery bypass grafts are present, we describe the type, origin, course, site of anastomosis, the presence, location, and degree of graft stenosis and also the quality of the run-off within the grafted vessel distal to the anastomosis. The presence and course of anomalous coronary arteries is noted, and also the coronary supply type (right-dominant, left-dominant or codominant). Finally, each coronary artery (left main, left anterior descending artery, circumflex, RCA) is separately commented on with regards to the presence and type of atherosclerotic plaque burden (calcified vs. noncalcified). For reporting the site of stenosis, use of the American Heart Association/American College of Cardiology segmental model, which is widely employed for research purposes, has proved less useful for routine clinical interpretation. We rather use the common terminology found in routine catheter reports, that describe lesions as located in the proximal, mid, or distal portion of the respective main coronary arteries or their side branches (left anterior descending artery: diagonals and septals, circumflex: obtuse marginals, RCA: acute marginals). We use our visualization methods (see above) to determine the severity of stenosis as the percentage of luminal obstruction, on the basis of cross-sectional measurements of vessel diameter or area.

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