Introduction

The current generation of multi-detector row CT (MDCT) with simultaneous acquisition of up to 16 slices enables scan speeds which are 45 times faster compared with single-slice CT [1, 2]. The scan speed translates into the ability to scan the entire thorax in just one breath hold of not more than 10 s [3, 4]. Despite submillimeter resolution, this scan speed allows motion-free images even in the most critically ill patients; however, the most important difference compared with conventional spiral CT is the conceptual change of acquiring a volume of data rather than individual sections [5]. This has also affected the techniques and protocols for contrast injection for various applications. After some technical remarks, we concentrate, in this article, on various applications of contrast-enhanced thoracic imaging. The main focus is on imaging of the thoracic aorta, the pulmonary arteries, and the pulmonary veins.

Examination techniques

High-concentration contrast

For MDCT of the aorta and thoracic vessels, using high-concentration contrast medium (400 mg I/ml) is recommended because it is essential to reach a high level of iodine rapidly [6]. This is particularly important using scanners that have a large number of detector rows (i.e., 8 or 16). A given volume of high-concentration contrast medium produces higher attenuation in the arteries compared with the same volume of standard contrast medium (300 mg I/ml). The use of high-concentration contrast medium has the advantages of facilitating postprocessing, allowing depiction of smaller vessels, and reducing the overall amount of contrast medium required by approximately 30% [6].

Saline flushing

Haage et al. demonstrated that injection of contrast material, followed by a saline-solution bolus using a double-power injector when performing thoracic helical CT, allows a 20% reduction of contrast material volume with a similar degree of enhancement [7]. In addition, peri-venous artifacts in the superior vena cava and in the subclavian vein were significantly reduced [8]. Presently, this examination technique is significantly facilitated by the fact that dual-power injectors are now widely commercially available. When using high-concentration contrast medium with MDCT saline flushing should be used on a routine basis for all contrast-enhanced CT examinations.

Gating and triggering

For reduction of heart motion artifacts and pulsation in the ascending aorta, various examination techniques are
Fig. 1 The ECG-gated cone-beam reconstruction (adaptive cardio multiple-plane reconstruction, ACMPR). Based on the general-purpose adaptive multiple-plane reconstruction (AMPR) multiple double oblique primary image planes with ECG-controlled selection of booklets are used for reconstruction. For thoracic applications the pitch is increased, i.e., by using two or three booklets in each cardiac cycle, the reconstruction window is widened at the expense of reduced temporal resolution. For a 16x0.75-mm collimation 12-mm/s table feed is possible which results in a scan time of <25 s to cover the entire thorax (300 mm) with a temporal resolution of 210–550 ms for 0.42-s gantry rotation time available. In single-slice CT only axial ECG-synchronized non-spiral scanning (“triggering”) is feasible which provides only limited z-resolution within a single breath-hold scan. With the introduction of MDCT retrospectively ECG-gated scanning allows for sufficient continuous volume coverage within reasonable scan times. Recently, a new technique for extended volume coverage with retrospective gating has been introduced. With this technique thin-slice data of the entire thorax can be acquired within one breath-hold period using a 4-slice CT system. The extended volume coverage is enabled by a modified approach to ECG-gated image reconstruction. For a CT system with 0.5-s gantry rotation time, images are reconstructed with 250-ms image temporal resolution. Instead of selecting scan data acquired in exactly the same phase of the cardiac cycle for each image as in standard ECG-gated reconstruction techniques, the patient’s ECG signal is used to omit scan data acquired during the systolic phase of highest cardiac motion. With this approach, cardiac pulsation artifacts in CT studies of the aorta, paracardiac lung segments, and coronary bypass grafts can be effectively reduced [9]. For 16-slice technology ECG-gated cone-beam reconstruction (adaptive cardio multiple-plane reconstruction, ACMPR) is available. Based on the general purpose adaptive multiple-plane reconstruction (AMPR) multiple double oblique primary image planes with ECG-controlled selection of booklets are used for reconstruction. For thoracic applications the pitch is increased, i.e., by using two or three booklets in each cardiac cycle, the reconstruction window is widened at the expense of reduced temporal resolution (Fig. 1). For a 16x0.75-mm collimation, 12-mm/s table feed is possible which results in a scan time of less than 25 s to cover the entire thorax (300 mm) with a temporal resolution of 210–550 ms for 0.42-s gantry rotation time.

Fig. 2 A 65-year-old man s/p bypass surgery. The extended volume coverage of ACMPR with higher pitch allows assessment of the entire course of the bypass grafts (arrows), from the proximal to the distal anastomosis, with high spatial resolution in one breath-hold period. Protocol: 16x0.75-mm collimation; 11-mm/s table feed; 80 cc Iomeron 400 (300 mm) with a temporal resolution of 210–550 ms for 0.42-s gantry rotation time (Figs. 2, 3, 4).

**Radiation dose**

Computed tomography accounts for considerable population-based radiation dose from radiographic diagnostic studies [10, 11]. When discussing examination protocols the radiation dose issue should always be included. Frequently, the technical factors for CT examinations are not appropriately adjusted on the basis of patient size and anatomy. Recently, attenuation-based on-line modulation of the tube current to reduce milliampere values (mAs) in CT examinations has become commercially available [12]. The CT projection data are analyzed in real time to determine optimal milliampere values for each projection angle. The tube current is reduced at those angular positions where the patient diameter and, consequently, attenuation, are small. Results from various groups demonstrate that this can be done without loss of image quality; thus, attenuation-based on-line modulation of the tube current seems to be efficient and practical for reducing dose exposure [13]. This is especially important when a CT scan for suspicion of pulmonary embolism (PE) is necessary in a pregnant patient.