Detection of Stent Fractures:

A Comparison of 64-slice CT, Conventional Cine-angiography, and Intravascular Ultrasonography[1]

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Rational and Objectives. We evaluated the ability of 64-slice computed tomography (CT), conventional cine-angiography, and intravascular ultrasound (IVUS) to detect stent fractures under ideal conditions. Coronary stent fracture has been implicated as one of the mechanisms of stent thrombosis and, perhaps, in-stent restenosis. However, the preferred imaging modality in detecting fractures in coronary stents has not been well established.

Materials and Methods. Four different types of commonly used coronary stents (Cypher, Taxus, Vision, Hepacoat) each with three strut fractures (Cypher, 5; Taxus, 5; Vision, 4; Hepacoat, 5) were nominally deployed in polyurethane tubes and imaged with 64-slice CT, conventional cine-angiography, and IVUS. For each stent type, an unfractured control stent was also imaged.

Results. Overall accuracy (84.1% vs. 73.9%), sensitivity (80.7 vs. 77.2%), and specificity (100% vs. 58.3%) for stent fracture detection was higher with 64 multislice CT compared to conventional cine-angiography. Stent fractures were not accurately detected by IVUS. Fracture detection by multislice CT was best when the stents were imaged at 45° to the z-axis.

Conclusions. Under ideal in vitro conditions, CT has a high accuracy when used to evaluate coronary stent fractures. The overall accuracy, sensitivity, and specificity of detecting stent fractures are lower by conventional cine-angiography. Stent fractures were not detected using IVUS.

Key Words. Tomography; imaging; coronary stents; fracture.

The medical use of stents has had a significant impact on the treatment of a wide array of medical conditions. Stents can be used in both vascular and nonvascular structures (eg, gastrointestinal/biliary tract, bronchial tree); stent fracture is a known complication in both types of settings (1–3). Excessive mechanical stress from extreme flexion of the vessel or compression by tissue has been proposed as a possible cause of some of these fractures (4). Coronary stents, which were reserved for bailout situations when they were first developed, are now used in more than 80% of the approximately 1,000,000 percutaneous coronary interventions performed annually in the United States (5). The efficacy of bare metal stents is limited by the occurrence of in-stent restenosis, which ranges from 15% to 35% in unselected cases, depending on lesion morphology and concomitant medical conditions (6).

The development of drug-eluting stents has proven to be very effective in suppressing neo-intimal proliferation and reducing subsequent in-stent restenosis (7). However, stent fracture is increasingly being reported as a complication of drug-eluting stent placement, and is believed to play a significant role in some cases of stent thrombosis as well as in-stent restenosis (8). Although most coronary stent fractures reported in the literature represent complete avulsion fractures detected by intravascular ultrasound (IVUS), there are a paucity of data on the preferred imaging modality for detection of individual strut fractures, which likely represent precursor events before complete stent avulsion. We

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therefore sought to compare the ability of several different imaging modalities to detect stent fractures.

MATERIALS AND METHODS

Four types of commercially used coronary stents were nominally expanded to 3.0 mm into commercially available clear polyurethane tubes using their respective stent delivery systems. The tubes all had an internal lumen diameter of 3 mm, and a radial wall thickness of 1.5 mm. The four types of stents used in this study were: Cypher, a stainless steel (316L grade) sirolimus-eluting coronary stent (n = 5, Cordis Corporation, Miami Lakes, FL); Hepacoat, a stainless steel (316L grade) heparin-coated coronary stent (n = 5, Cordis Corporation); Vision, an uncoated cobalt-chromium coronary stent (n = 4, Abbot Vascular, Abbot Park, IL); and Taxus, a stainless steel (316L grade) paclitaxel-eluting coronary stent (n = 5, Boston Scientific, Natick, MA). Before stent deployment, a miniature wire cutting tool was used to create stent strut fractures in three discrete locations, whereas one nonfractured stent of each type served as controls. Fractures were arranged so that no two fractures were made in any immediately adjacent stent cells. The size, length, strut thickness, and density of the stents used in this study are summarized in Table 1.

After stent deployment, the internal lumens of the tubes were completely filled with iohexol-350 at a dilution concentration of 1 mL (755 mg iohexol/mL) of iohexol to 39 mL of 0.9% normal saline. The radiodensity of the final contrast dilution was approximately 260 Hounsfield units (HU). The tubes were then sealed, and each placed inside larger saline-filled polyurethane tubes to reduce artifact during computed tomographic (CT) imaging.

CT Angiography

The stented polyurethane tubes were imaged in a 64-slice CT scanner (Sensation 64, Siemens Medical Solutions, Malvern, PA) with retrospective electrocardiographic gating, using section collimation of 0.6 mm, pitch of 0.2, gantry rotation time of 330 ms, tube potential of 120 kV, and effective tube current-time product of 650 mAseff. The stents were scanned at scan angles of 0°, 45°, and 90° to the z-axis. An artificial electrocardiographic signal generated by the scanner at a rate of 71 beats/min was used for data reconstruction. The field of view was 160 mm with a matrix of 512 × 512. The data sets were retrospectively reconstructed at 55% of the RR interval with a section thickness of 0.75 mm and an increment of 0.5 mm using the B46f convolution kernel. Images were reconstructed using the same parameters that are used in the clinical settings for the evaluation of coronary arteries. Multiplanar reformations perpendicular and parallel to the stent axis were evaluated on an image processing workstation (Siemens Leonardo, Malvern, PA) using the window setting of center 1000 HU and width 2000 HU. Several window settings were evaluated before examining the stents for fractures. These included center 600 HU and width 3000 HU, center 1000 HU and width 2000 HU, center 700 HU and width 2000 HU, center 200 HU and width 700 HU, and center 300 HU and width 1500 HU. The investigators found the window center of 1000 HU and window width of 2000 HU to be optimal for the visualization of the struts.

Table 1
List of Stent Types Used

Stent type	Size (mm)	Strut thickness (mm)	Hounsfield Density
Vision	3.0 × 23	0.08	1091 ± 72
Hepacoat	3.5 × 8, 3.5 × 13	0.14	700 ± 22
Taxus	2.75 × 12	0.13	937 ± 50
Cypher	3.0 × 23	0.18	1025 ± 35

Conventional Cine-angiography

The stented tubes were also imaged with conventional cine-angiography using a Philips Integris cine-fluoroscopy system (Philips Medical Systems, Andover, MA). The images were captured at 30 frames/s, with a trimodal image intensifier, a 17-cm field, and a 512 × 512 pixel array. A tube potential of 50 kV and a 500-mA current were used. The spatial resolution was 3.7 line pairs per millimeter. The stents were imaged at angles of 0°, 45°, and 90° to the z-axis.

Intravascular Ultrasound

IVUS was also used to image the stented tubes (Galaxy[2] IVUS System, Boston Scientific). A 40-MHz, 2.5 French, Atlantis SR Pro imaging catheter (Boston Scientific) was placed into the stented polyurethane tube. A slow, mechanical rotary pullback method was used to detect the stent fractures.

Image Analysis

Two investigators, blinded to stent type, fracture status, and number of fractures in each stent were then asked to evaluate images of the fractured as well as control stents obtained from all three imaging modalities to assess for the binary presence or absence of any fracture (stent fracture detection). If fracture was deemed present, the exact number of struts that were fractured (strut fracture detection) was also assessed. An exact identification of three discrete strut fractures was required to be classified as a successful and accurate detection of strut fracture (ie, detection of two or four strut fractures was deemed inaccurate). Determination of stent as well as strut fracture was made by consensus.