Introduction
Extracellular MR contrast agent gadolinium has been used for first-pass perfusion imaging of lung parenchyma and/or 3D MR angiography of pulmonary vasculatures (1-5). The former was typically obtained by a 2D gradient-echo sequence, which has limited spatial coverage. The latter requires precise timing of the start of contrast injection, breath-hold, and data acquisition. Moreover, the contrast-enhanced MRA is not repeatable due to fast diffusion of the contrast agent to the interstitial space.

In this report, we present a time-resolved 3D pulmonary perfusion imaging, followed by a 3D high-resolution pulmonary angiography for detection of pulmonary artery defects in an animal model. All studies were performed after a single injection of a new intravascular agent.

Material and Methods
Animal Model
Five domestic pigs (22-27 kg) were used in this study. An 8-F sheath/dilator was inserted into the right internal jugular vein as a conduit for the clots and contrast injection. The pigs were mechanically ventilated and anesthetized through a mixture of oxygen and isoflurane. To block the pulmonary artery flow, different sizes of gelatin foams (Pharmacia & Upjohn, Kalamazoo, MI) were rapidly injected into the superior vena cava through the sheath by fast flush of normal saline.

MR Imaging
The 3D perfusion sequence was a time-resolved 3D gradient-echo sequence. The sequence parameters included: TR/TE=1.64/0.6 msec, FOV = 298 x 340, matrix = 140 x 256, slab thickness = 100 mm, 3D partition = 32, and flip-angle = 15°, yielding the image voxel size of 2.1(y) x 1.3(x) x 3.1(z) mm³ and temporal resolution of 3 sec per 3D data set. The 3D MR angiography was obtained by another fast 3D gradient-echo sequence with parameters of TR/TE=3.2/1.1 msec, FOV = 263 x 300, matrix = 256 x 512, slab thickness = 105 mm, 3D partitions = 96, flip angle = 25°. The image resolution is 1.0(y) x 0.6(x) x 1.1(z) mm³ and imaging time is 31 sec. All 3D slice thickness was interpolated. The studies were performed on a commercial 1.5-T system (Symphony Sonata, Siemens Medical Systems, Erlangen, Germany). The new intravascular agent B22956/1 is a gadolinium chelate with a lipophilic group, developed by Bracco (Bracco SPA, Milan, Italy), which has a long blood pool half-life and 6-fold higher T1-relaxivity than Gd-DTPA.

Imaging Protocol
The pigs were positioned supine during the scan. First, baseline 3D perfusion images were acquired on the normal pigs without introduction of the clots by a 1.5-set injection of a 0.1-mmol/kg extracellular agent Prohance through the sheath. The injection started 6-sec after the start of twelve 3D data acquisitions. Normal parenchyma perfusion images were obtained by subtracting the second 3D data set from the 3'D, 4'D, 3D data set. After one and half hour, the gelatin foams were then introduced to the pigs. A single dose (0.1 mmol/kg) B22956/1 was injected within 1.5-sec into the pig and data acquisition started as previously described. After finishing the 3D perfusion imaging, 3D MR angiography was performed. Each imaging scan was performed under a single breath-hold by stopping the ventilation.

Results
All 3D perfusion images showed volumetric parenchyma perfusion maps with high signal-to-noise ratio. Different perfusion defects were well visualized in different views of the 3D perfusion data. Figure 1 shows the normal perfusion maps (a) and multiple wedge-shaped defects (b, arrows) after injecting the gelatin foams. The image (c) in Fig. 1 is one 3D high-resolution MRA from a MIP data set, demonstrating the blockage of the right low-lobar segmental pulmonary vessel (thick arrow), which could be identified from different views of the MIP images. Figure 2 shows the perfusion curves from the normal perfused right lung and under-perfused right base lung.

Conclusions
3D fast perfusion and angiography imaging, combined with intravascular agents, offer whole-lung-coverage perfusion maps and angiography in one setting for detecting pulmonary defects. Further study may be needed to quantify the perfusion information and separate arteries and veins in the angiography acquired after injection of the contrast agents.

References