Dynamic dual-energy x-ray techniques for cardiac imaging

Sabee Y. Molloi

Previous attempts to use time subtraction Intravenous Digital Subtraction Angiography (IV DSA) for ventricular imaging have been hampered by artifacts due to cardiac and respiratory motion. As a solution to these well-known misregistration problems, a dual-energy (DE) fluoroscopy mode was investigated and tested in animals and human volunteers. In order to overcome the intensity limitations of the k-edge fluoroscopy mode previously reported, a non-k-edge technique in which x-ray tube voltage and x-ray beam filtration were switched at 30 Hz between 60 kVp (2.0 mm Al filtration) and 120 kVp (2.0 mm Al + 2.5 mm Cu filtration), was studied.

The potential advantages of the DE technique for motion-immune enhancement of coronary angiograms were assessed by subjectively comparing DE, unsubtracted low-energy (L) and high-pass (HP) filtered L images of selective canine coronary angiograms. Although HP filtration permitted some contrast enhancement, the images had a greater amount of distracting tissue background than the DE image. The DE mode also allows for rotation of the x-ray tube and the image intensifier during image acquisition. The resulting DE images provide a continuum of viewing angles during vessel opacification.

To assess the feasibility of the DE mode for large patient thickness, optimized iodine S/N ratio was measured as a function of phantom thickness. Using a fixed mAs, the S/N ratio of the DE images was found to decrease by seven fold as lucite thickness increased from 10 to 25 cm. For the same increase in lucite thickness, S/N for time subtraction images decreased by five fold. Image quality in two human volunteers was subjectively judged to be good.

In order to quantitate physiological parameters such as ejection fraction and left ventricular volume, energy dependent corrections for scatter and veiling glare (SVG), beam hardening, detector nonuniformity, heel effect, and uncancelled bone signals were developed. Among these, SVG are the major sources of nonlinearity in videodensitometric measurements. A convolution filtering method was investigated to estimate SVG in DSA images. A grey level transformation of the detected image was utilized to get a first-order SVG image. In the second step this image was convolved to produce an image with appropriate spatial frequency content.

In a phantom measurement simulating exercise ventriculography, the known ($V_{\rm k}$) and videodensitometrically measured ($V_{\rm m}$) volumes of 19 mg/cm^3 solution of iodine was related by $V_{\rm m} = 0.95 V_{\rm k} + 1.50$ cc ($V > 0.99$).