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# Digital Coronary Roadmapping as an Aid for Performing Coronary Angioplasty

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**In an attempt to improve visualization of the position of the guidewire and dilatation balloon during coronary angioplasty, a method was developed called digital coronary roadmapping. With this method a digitally acquired coronary angiogram is interlaced with the live fluoroscopic image of the guidewire and balloon catheter. The digital coronary angiogram is superimposed at the same magnification and ra-**

**diologic projection as the live fluoroscopic image onto the video monitor above the catheterization table. The digital roadmap image thus provides immediate feedback to the angiographer to assist in directing the guidewire into the appropriate coronary artery branch and to help in placement of the balloon so that it straddles the site of stenosis.**

**(Am J Cardiol 1985;56:237-241)**

One of the major advances in the performance of percutaneous transluminal coronary angioplasty (PTCA) has been the development of steerable guidewires.<sup>1-6</sup> Although the steerable systems have improved maneuverability, there are still technical problems with positioning of the guidewire and dilatation balloon because adequate visualization of the coronary arteries is often difficult during passage of the balloon and guidewire.

In an attempt to improve the physician's ability to position the guidewire and balloon during PTCA, a method was developed called digital coronary roadmapping that uses a video mixer to superimpose an opacified digital subtraction angiographic image of the coronary arteries onto the live fluoroscopic images of the guidewire and balloon catheter.<sup>7</sup> This digital image of the coronary anatomy thus acts as a reference or roadmap during passage of the guidewire and balloon catheter to insure proper direction of the guidewire into

the desired balloon artery branch and proper placement relative to the stenotic site.

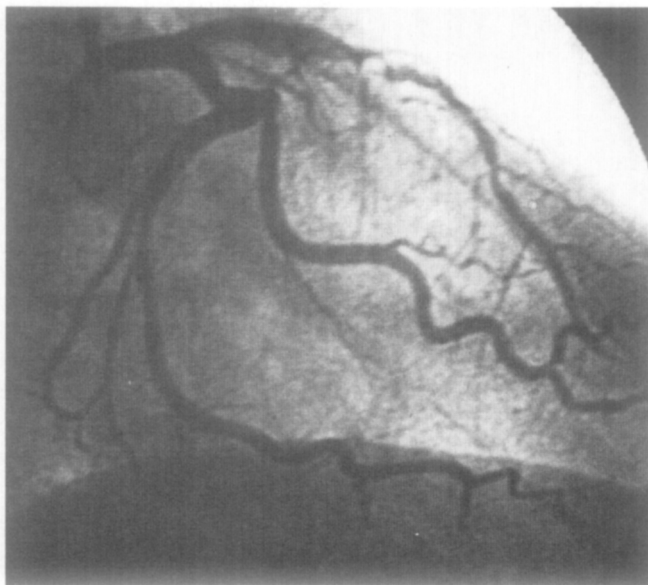
## Methods

**Study group:** Thirty-one patients who were undergoing PTCA for clinically indicated reasons participated in this study. There were 19 men and 12 women, aged 41 to 74 years (mean 58). Nineteen patients had a single stenosis of a single artery, 4 patients had 2 arterial stenoses in the same or different arteries, 6 patients had 3 stenoses and 2 patients had 4 stenoses. Seven of the 31 patients had PTCA performed after recurrence of symptoms, 4 after coronary bypass surgery and 3 because of a restenosis after a prior angioplasty.

**Digital angiography system:** For digital acquisition of angiograms, the x-ray exposure was transmitted from the image intensifier by a progressive scan camera (Hamamatsu Corp.) and digitized in real time into a 512 × 512 × 8-bit-deep pixel matrix by a commercially available digital angiography computer (Fischer DA-100). Digital images were obtained either at 8 or 30 frames/s and stored on a 480-megabyte rapid parallel transfer digital disk. The x-ray exposure settings ranged from 75 to 90 kVp at 800 mA using a Gigantos-Optimatic x-ray generator. The exposure time during digital angiography was 10 ms/frame. A detailed description of our method for obtaining selective coronary digital angiograms has been reported.<sup>8</sup> Digital angiograms were obtained in multiple projections which included 2 orthogonal projections as well as cranial and caudal angulated views. The digital angiograms were reviewed in an unsubtracted format within 2 minutes after acquisition.

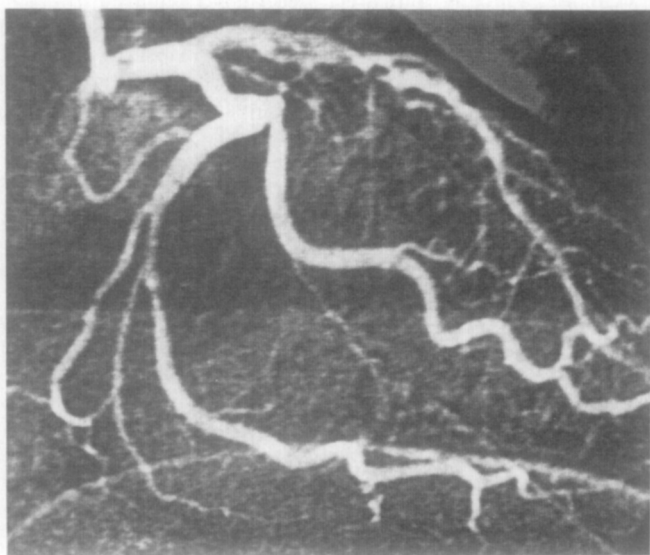
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**FIGURE 1.** Photograph from the computer monitor of an unprocessed digital coronary angiogram taken in the 30° right anterior oblique projection. There is a severe stenosis in the proximal portion of the left anterior descending artery at the level of the septal perforator.

**Roadmap procedure:** The method of obtaining the roadmap during PTCA is illustrated in Figures 1 and 2. Before insertion of the dilatation catheter, baseline digital coronary angiograms were obtained. One end-diastolic frame was chosen from the projection that best delineated the stenotic coronary artery and demonstrated any bifurcations of nearby arterial branches. Figure 1 is a photograph from the computer monitor of a selective digital coronary angiogram obtained in the 30° right anterior oblique (RAO) projection. The image is in an unprocessed format and demonstrates a severe stenosis of the left anterior descending coronary artery (LAD) at the level of the septal perforator. This digital frame was



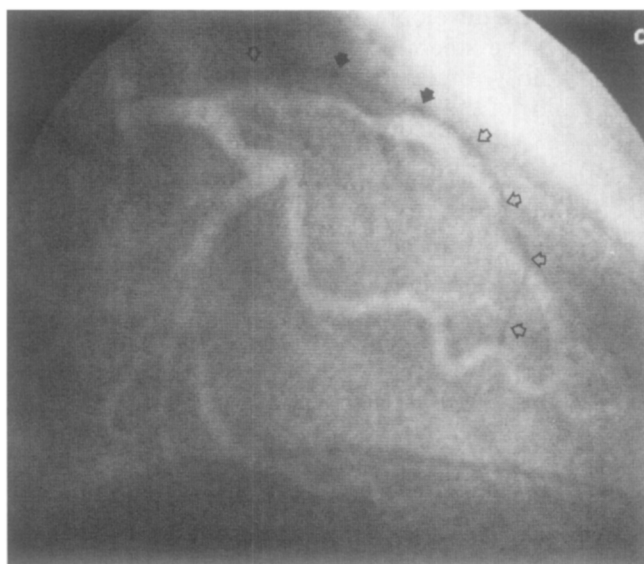
**FIGURE 2.** The unprocessed digital image taken at end-diastole was processed through the computer by mask-mode subtraction, contrast reversal and contrast enhancement algorithms. This isolated image of the native left coronary artery is called the digital roadmap and is stored in computer memory.

then processed by mask-mode subtraction for use as a roadmap (Fig. 2).<sup>9-13</sup> This subtracted image of the coronary artery was processed by the computer to alter black and white levels, reverse contrast and vary background brightness. The projection used to perform the coronary angioplasty was the same projection used to obtain the roadmap.

**Use of the roadmap:** The subtracted image of the coronary artery to be used as the roadmap was stored in a separate computer memory file for rapid recall during the procedure. This creation of the roadmap was performed by the x-ray technologist while the angiographers were preparing the balloon dilatation system and loading it into the guiding catheter.

The digital roadmap image was recalled from computer memory and displayed on the computer monitor. The video output of the computer monitor was connected to 1 of 2 inputs of a video mixer (Sony SEG-1A special effects generator). The other input into the video mixer came from the television camera of the x-ray fluoroscopy system. The video mixer interlaced the subtracted roadmap image of the coronary artery with the live fluoroscopic image of the patient. The output signal of the video-mixed image was connected to the television monitor above the catheterization table. Using a switch on the video mixer, the live fluoroscopic image could be displayed on the television monitor alone or superimposed on the roadmap image. The video level of the roadmap image was varied so that the coronary roadmap did not interfere with visualization of the balloon dilatation catheter and guidewire from the fluoroscopic image. With the interlaced digital roadmap image on the catheterization table monitor, the steerable guidewire was inserted and visualized as it passed over the opacified coronary image of the roadmap.

The interlaced image of the digital roadmap and the live fluoroscopic image was recorded on 3/4-inch videotape as the guidewire or balloon catheter was advanced. Figure 3 is a photograph from the video monitor of a still frame of the



**FIGURE 3.** The digital roadmap (Fig. 2) is recalled from computer memory and interlaced through a video mixer with the live fluoroscopic image of the heart. The roadmap digital image is kept on the monitor above the catheterization table as the angiographer advances the dilatation guidewire and balloon. In this stop-frame image from the videotape, the guidewire (open arrows) is seen parallel to the left anterior descending artery and the dilatation balloon metallic markers (closed arrows) are seen approximating the site of the stenosis as visualized on the roadmap.

videotape during playback. Although the still-frame mode of demonstrating video images significantly degrades image quality, it is possible to see the roadmap of the native left coronary system (Fig. 2) superimposed on the fluoroscopic image of the guidewire and balloon dilatation catheter.

Once the guidewire has been positioned in the appropriate branch vessel, the dilatation balloon catheter is advanced over the guidewire with the roadmap as a reference until the metallic markers of the balloon are seen to straddle the coronary lesion. In Figure 3 the metallic markers (closed arrows) of the dilatation balloon can be seen to straddle the position of the stenosis demonstrated on the roadmap. The postdilatation result is shown in Figure 4.

An alternative method for using the digital roadmap technique is illustrated in Figures 5 and 6. Figure 5 is a photograph of an unsubtracted digital angiogram in the 30° RAO projection with 45° caudal angulation after injection of contrast material into the native left coronary artery system. Several regions of narrowing of the left main, LAD and circumflex arteries are visualized. The patient from whom this image was taken had had coronary artery bypass surgery 3 months earlier and had recurrence of angina pectoris. Retrograde flow of contrast media can be seen filling the distal anastomosis of a saphenous view bypass graft to the obtuse marginal artery (arrows). There are stenoses at the anastomotic site proximal and distal to the insertion of the bypass graft.

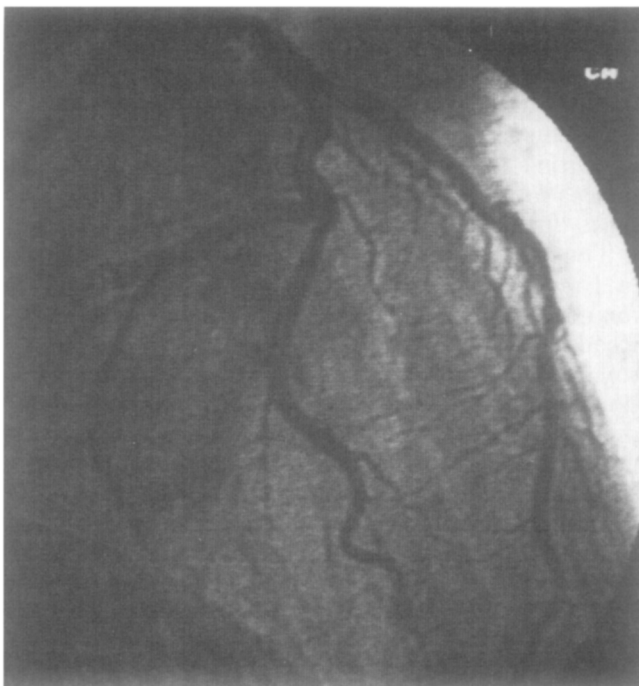
During the angiographic study, a digitally subtracted image was created for use as a roadmap (Fig. 6). During this PTCA, the guiding catheter was engaged in the obtuse marginal bypass graft and the guidewire was advanced through the bypass graft to the anastomotic site. With the digital coronary of the previously injected native left coronary artery as a reference on the monitor, the guidewire was manipulated distally into the obtuse marginal artery. The dilatation balloon was advanced over the guidewire and positioned at the anastomosis. The distal stenosis was dilated using the roadmap as a guide

for proper positioning of the balloon. Next, the wire was re-directed retrograde into the proximal native circumflex artery and the proximal anastomotic lesion was dilated as well as the proximal native circumflex artery. In this patient, the location of branch vessels and the position of coronary stenoses were visualized by the roadmap even though no catheter was in the native coronary artery during angioplasty to provide even transient opacification.

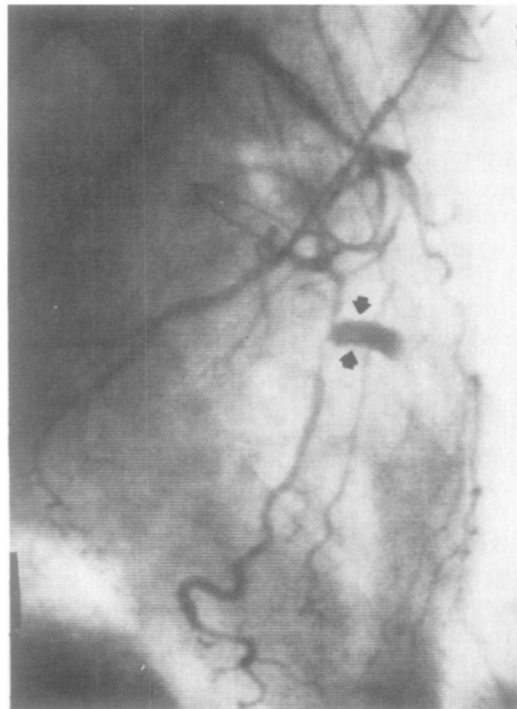
## Results

During the period of this study (March to July 1984) 31 patients underwent PTCA with digital coronary roadmapping. Angioplasty was attempted in 53 coronary artery segments. The distribution of these narrowed segments were: 2 left main, 18 LAD, 12 diagonal, 16 circumflex and obtuse marginal, 1 ramus intermedius, 9 right coronary artery, 3 posterior descending, and 2 bypass graft stenoses.

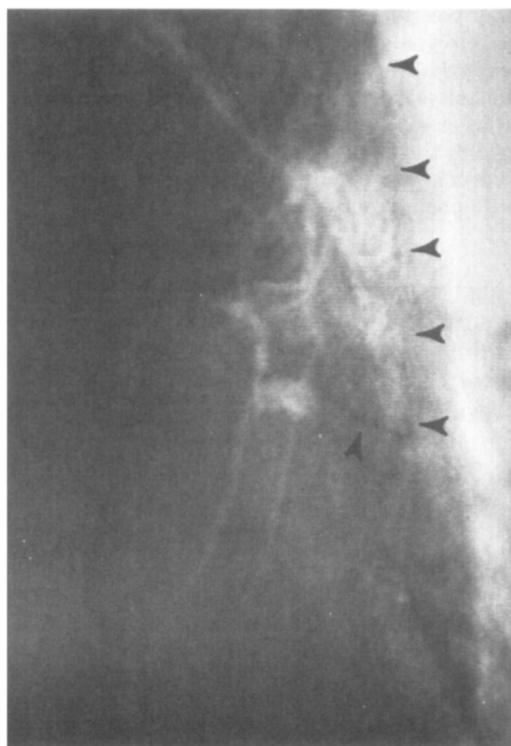
Of the 53 stenotic segments that were approached with digital roadmapping as a guide, 48 (91%) were primary successes. Digital angiographic roadmapping was considered to be beneficial if it either helped in directing the guidewire into appropriate arterial branches or if the roadmap was useful in aligning the balloon directly over the coronary obstruction. Using this definition, digital roadmapping was found to be beneficial in 46 of the 48 primary successful dilatations. In 2 cases, the roadmap was misleading. In these cases the ramus intermedius and the LAD closely paralleled



**FIGURE 4.** Postangioplasty selective digital coronary angiogram taken in the 30° right anterior oblique projection with 45° of caudal angulation showing a significant increase in luminal diameter.



**FIGURE 5.** Unsubtracted digital angiogram after selective cannulation of the native left coronary artery. The angiogram was obtained in a 30° right anterior oblique projection with 45° of caudal angulation. There is diffuse arterial narrowing involving a long left main artery and left anterior descending and circumflex arteries. Note the retrograde filling of the aortic bypass graft to the obtuse marginal artery (arrows). Significant stenoses proximal and distal to the bypass anastomosis are visualized.



**FIGURE 6.** The digital roadmap is recalled from computer memory and interlaced through a video mixer with the live fluoroscopic image of the heart. In this image, the dilatation catheter was inserted into the aortic bypass graft to the obtuse marginal artery and the guidewire can be visualized (arrows) as it approaches the anastomotic site with the native obtuse marginal artery. The angiographer used the roadmap image to help guide the dilatation wire and balloon down the distal obtuse marginal segment and then retrogradely into the proximal circumflex artery for dilatation at multiple sites, despite the absence of a catheter in the native artery to provide contrast visualization.

each other in the RAO projection. The roadmap suggested that the guidewire was situated within the LAD, but the position of the guidewire initially was not confirmed by imaging in the left anterior oblique projection. During the attempted dilatation, adequate contrast media could not be injected into the left coronary ostium to adequately visualize the relative position of the arteries. However, when the image intensifier was moved into the left anterior oblique projection, it was apparent that the guidewire and balloon catheter were in the ramus branch and not the LAD.

### Discussion

Coronary angioplasty is having a significant impact as an alternative to coronary artery bypass surgery for improving blood flow in patients with coronary atherosclerosis.<sup>14-17</sup> The initial recommendations were to perform PTCA only on proximal, 1-vessel obstructions in patients whose symptoms were relatively brief (less than 6 months).<sup>18-21</sup> As catheter design improved and steerable guidewire techniques were developed, several groups became more aggressive in applying PTCA to multiple lesions in the same or different arteries, to distal lesions, and to lesions at arterial bifurcations.<sup>22-27</sup> As with any technical procedures, the success of PTCA improves with the operator's experience and with improvements in equipment design.<sup>28-29</sup> Adequate visu-

alization of the coronary anatomy is another major area that affects the facility for performing PTCA.

Several factors may cause poor opacification of the coronary arteries during PTCA, including difficulty with engaging the guiding catheter into the coronary ostium, back flow of contrast material through the Y adaptor during injection, or the high resistance to injection of contrast material when the guiding catheter is loaded with the dilatation balloon catheter.<sup>30,31</sup> In addition, the contrast material that is injected is only transiently visualized on the fluoroscopic monitor. Another problem with adequate visualization is that prior coronary angiograms on 35-mm film frequently are used as a reference to guide the operator. However, these films are often several months old and may have been taken in slightly different projections than the live fluoroscopic images used during passage of the dilatation balloon catheter and guidewire. Furthermore, the cine films are visualized on a different screen in the catheterization laboratory and at a different magnification than the live fluoroscopic television monitor that the operator uses during the angioplasty procedure.

Some of the features of digital angiography can be used to address these problems with coronary visualization during PTCA. The first benefit of digital acquisition of angiograms is that the images are immediately available for review because there is no film to develop. During interventional angiographic procedures, immediate recall of angiograms is critical in making decisions concerning the effects of the intervention and in deciding if additional procedures should be performed. The second advantage of digital acquisition is with the images can be manipulated within the computer to enhance visualization of the coronary arteries that such processes as mask-mode subtraction, edge enhancement and digital magnification. In addition, quantitative analysis of atherosclerotic luminal narrowing can be performed before and after PTCA to quantify the angiographic results of the intervention while the patient is still in the laboratory.<sup>32</sup> The third advantage of digital acquisition is that the enhanced images can be stored in a computer memory for rapid recall during the intervention procedure.

The use of digitally acquired images as a visual aid in transluminal angioplasty was initially described for peripheral artery stenoses by Crummy et al.<sup>33,34</sup> Roadmapping during peripheral artery angioplasty is somewhat simpler because the artery is relatively stationary during the procedure. Correct positioning of the dilatation catheter may be more difficult during coronary angioplasty because of the translational motion of the artery during the cardiac cycle. In the present study, the roadmap used was a digital subtraction image of the coronary artery that was obtained at end-diastole. The roadmap was recalled from computer memory and mixed with the live fluoroscopic image of the heart. On this composite live image, the guidewire could be observed as it was advanced to follow the opacified image of the coronary arteries. This method was very useful during the manipulation of the guidewire into the correct branch of the artery to be dilated. The roadmap also gave the angiographer immediate feedback concerning

the position of the balloon relative to the stenotic segment during advancement of the dilatation balloon. The process of interlacing the digital roadmap image with the live fluoroscopic image so that both images were visualized on the same screen and at the same magnification is an important advantage over previous imaging techniques.

In this series of 31 cases, digital angiographic roadmapping was found to be beneficial in directing the guidewire and correctly placing the dilatation balloon in 46 of 48 primary successful dilatations. Difficulties were encountered with the roadmapping procedure in 2 patients. In these patients, the roadmap incorrectly suggested to the angiographers that the guidewire had been successfully passed into the LAD. Thus, although the roadmap is a useful adjunct to angioplasty, other means of identifying anatomy and checking the position of the dilatation system should be performed.

Another problem with the roadmapping technique is misregistration between the image used to form the roadmap and the live fluoroscopic image. During real-time fluoroscopic monitoring, the guidewire and balloon dilatation catheter move with the epicardial artery during the cardiac cycle. Because the roadmap is taken from an end-diastolic frame, when cardiac motion is relatively stable, there is misregistration of the roadmap and live fluoroscopic image throughout all but the end-diastolic portion of the cardiac cycle. Despite misregistration, the roadmap was useful because the brief alignment of the roadmap and live fluoroscopic image at end-diastole provided sufficient visualization of the position of the guidewire and balloon relative to the roadmap. As computer technology improves, it should be feasible to continuously update the digital roadmap throughout the cardiac cycle using electrocardiographically gated coronary images.

In summary, digitally processed coronary angiograms can provide a guide, or roadmap, of coronary anatomy. The digital angiogram roadmap is obtained at the same magnification, and interlaced on the same television monitor as the live fluoroscopic image of the heart. This roadmap serves as a reference for positioning the steerable guidewire into specific coronary branches. In addition, the roadmap facilitates the alignment of the dilatation balloon relative to the stenotic segment. Based on our experience with this method, we believe that digital coronary roadmapping is a helpful adjunct to coronary angioplasty. Although highly experienced angioplasty physicians who have performed several hundred angioplasty procedures may not benefit from this method, the angiographers who have performed fewer procedures may well find that this method improves their success rate of performing transluminal coronary angioplasty.

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