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EDITORIAL COMMENT

Dethroning Contrast Angiography

A Place for Electroanatomic Mapping?*

Neal S. Kleiman, MD

It was once commonly believed that "There is no question that 10 ccs of contrast can't answer." Although virtually everyone in medical practice today knows that this statement is untrue, it remains the maxim by which interventional cardiologists live. Most radiologists and interventional cardiologists readily admit that at some point the use of a radiocontrast system, consisting of a radiation-emitting source and detector, iodine-based contrast media, and appropriate radiation shielding ultimately can and should be replaced. The drawbacks of such a system are well known. Concerns apply to operators as well as to patients (particularly younger patients undergoing interventional procedures to treat congenital heart disease who are more prone to radiation's mutagenic effects). They include rare cases of anaphylactic reactions to contrast media and occasional skin burns as well as malignancies and more commonly observed radiation-induced cataracts and contrast-induced nephropathy. The ergonomics of shielding catheterization suites and of applying lead aprons have also proven rather onerous, have spawned a small industry dedicated to devices designed to relieve back strain among operators, and have even led to the development of rudimentary robotic devices that allow an operator to be seated comfortably at a safe distance from the x-ray source.[1] Radiation burns are extremely rare and require high doses of ionizing radiation to a limited skin field. Although the frequency of malignancies among interventional cardiologists is still indeterminate, the radiation doses used therapeutically have been shown induce cellular changes among operators, thereby increasing the potential for malignancy and other tissue damage.[2] The lens is probably the tissue most sensitive to the effects of radiation; posterior subcapsular lens changes have been reported in approximately half of interventional cardiologists and more than 40% of nurses and technicians, whereas the frequency in other medical personnel is <10%.[3] The adverse effects of contrast on kidney function are also well known. A recent study from the NCDR Cath-PCI Registry found that acute kidney injury (AKI) occurred in nearly 9% of 453,475 patients undergoing coronary interventions, and was associated with significant risk for recurrent AKI, as well as a >60% increase in the risk of death and a 30% increased risk of myocardial infarction, even 1 year after hospital discharge.[4]

Mapping techniques that provide anatomic and functional representations of the heart without requiring contrast or radiation have gained acceptance within the field of invasive cardiac electrophysiology. Intracardiac and transesophageal echocardiography have allowed some transcatheter aortic valve replacement procedures to be performed with minimal fluoroscopy and without contrast. There has also been a movement to eliminate contrast use completely during percutaneous coronary intervention (PCI), defining vascular landmarks using interventional guidewires rather than contrast injections, and using intravascular ultrasound imaging to assess the results of the procedure. Laudable efforts have been made in this direction. However, the overwhelming bulk of coronary interventions remain dependent on contrast angiography leaving the latter goals aspirational rather than realistic for the broader interventional cardiology field.

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From the Houston Methodist DeBakey Heart and Vascular Center, Houston, Texas, USA.

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In this issue of *JACC: Basic to Translational Science*, Dorval et al [5] conducted a proof-of-principle study designed to carry this movement forward. They placed stents in experimental swine using an electroanatomic navigation system that is currently is used for electrode placement during electrophysiology procedures (EnSite, Abbott Medical). Guidewires and stent balloons were modified so that they could be detected using the mapping system. Experimental animals underwent computed tomography (CT) angiography to define their vascular anatomy. Two decapolar catheters were then placed fluoroscopically in the right atrium and great vessels to provide fiduciary markers so that the CT images and mapping system coordinates could be coregistered with these landmarks. In the first series of experiments, catheters were navigated through the target vessels. Virtual target lesions were created and devices delivered to them. Stents were deployed and stent apposition to vessel wall was confirmed using optical coherence tomography. In the final series, real targets were created by first placing short stents in the vessels. The animals then underwent stent placement in the carotid and coronary arteries guided entirely by the mapping system. The investigators found that they were able to calibrate distances with >90% accuracy and to place balloons and stents in the appropriate locations in 9 of 11 attempts. Although processing the data required 23 minutes, the actual navigation required only 8 seconds.

The experiment was a success. Carotids and coronary arteries could be mapped, guidewire positions could be detected, and stents could be placed at or very close to the desired locations. However, it is important to recognize that the current study represents a very early stage in the move to robotic mapping, and that very daunting challenges remain. First, from a global clinical perspective, as the decision to perform PCI progresses, radiation and contrast exposure will still be required. Here their use is shifted from the PCI to the pre-procedure phase as CT angiography is used to delineate the vascular anatomy. CT coronary angiography in humans involves less radiation than is usually used in PCI but requires approximately 100 ml of contrast. The rate of AKI is lower with intravenous rather than intra-arterial injection (likely caused by the higher concentrations seen by the kidneys after intra-arterial injection), but it is still a significant concern. From the PCI perspective, guidewires and balloons for these experiments had to be modified to be detected by the mapping system. Guidewires had to be electrically insulated and a 0.014-inch wire had to be crimped between the stent and the deployment balloon. Although this was performed successfully, it is not clear how much the deflated balloon profile had to be changed and whether the stents would be as deliverable and the guidewires as maneuverable as current generation devices. In addition, calibration of the mapping device had to be performed, assuming that the geometry was Euclidean. The experimental animals did not have excessively tortuous or rigidly calcified vessels as are presently seen in patients undergoing complex PCI procedures. Other issues remain as well. Often, as one tries to advance a balloon through a narrowed and tortuous vessel, pushing the balloon forward dislodges the guiding catheter in accordance with Newton's first law. How then does one coordinate, eg, the interdependent motions of guiding catheters and balloons or stents? Additionally, without contrast, how would one detect vascular perforations, which although rare, usually require immediate action to avoid disastrous consequences?

Most important, adopting such a system is likely to require a sea change in interventional cardiologists' thinking. Interventional cardiology is, by nature, a visually based field, much more so than cardiac electrophysiology, for example Interventional cardiology largely consists of an effort to alter vascular geometry, and it can be argued that the urge to inject contrast is partly driven by biologic imperative. As anyone who has stared over a cliff edge can attest, and as neurobiologists have conclusively demonstrated, the visual cortex exerts a dominant influence on decision making and is easily able to override commands from the frontoparietal cortex that is involved in higher level cognition and decision making.[6] In other words, it is going to become difficult to surrender the visually directed choices that have for decades driven interventional cardiologists. We have seen this difficulty in other areas. For example, intravascular ultrasound has been available for more than a decade and has been shown in several randomized trials to reduce stent thrombosis and the need for target vessel revascularization. However, intravascular imaging is used in a very small minority of PCIs in the United States; even in the most recent trial, PCI with bypass surgery for patients with multivessel disease, it was used in very few patients. Dorval et al[5] predict that interventional cardiology will shift to a mapping-based field in the "near future." Although this statement may be true from a geologic perspective, it is still likely to be quite a while before contrast angiography is displaced in the field of coronary intervention. Experiments such as the ones described by Dorval *et al*[5] represent very early steps in that direction, but they are going to be crucial in leading us there.

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ADDRESS FOR CORRESPONDENCE: Dr Neal S. Kleiman, Houston Methodist Hospital, 6565 Fannin Street, MS WT-4-3020, Houston, Texas 77030, USA. E-mail: nkleiman@houstonmethodist.org.

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