Image-guided intervention and therapy

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In 2006, Dr. Elias Zerhouni, director of the National Institutes of Health, outlined the vision that "Medicine in the future has to be predictive, personalized, and very precise to the individual, and it has to be pre-emptive" [1]. He stressed the important role of imaging in understanding complex biological systems, a topic we reviewed in FTM-2006 [2]. A second and perhaps even bolder vision he articulated was "Twenty-five years from now, I hope that we won't perform any more open surgery. There would be no need to essentially take the risk of full exposure of the human body to go to a targeted region that needs to be affected." How this might be achieved is the topic I plan to address at FTM-2015.

In cardiology, one of the main causes of mortality today, major progress has already been made through minimally invasive interventions, such as placing a stent. Further, heart rhythm disorders can now be treated using catheters, by first mapping the disturbed pattern of electrical activity around the heart chambers, followed by selectively altering the current paths through local ablation of tissue. Valve replacement is also rapidly gaining ground. These procedures require careful navigation and steering of the various catheters, which can be optimized using 3D x-ray and ultrasound imaging methods, fused in real time with physiological models and image processing – thereby enabling proper eye-hand coordination.

However, a catheter today is a purely mechanical device, controlled via external imaging and manual steering. Our vision for the future is that the efficiency and positive outcome of catheter-based cardiovascular procedures can be drastically improved by adding in-body sensing and imaging to catheters. Advances in miniaturization technology will allow us to build intelligence into the catheter, to provide local imaging, localization and control capabilities. Examples of this are MEMS-based ultrasound transducers that can be mounted onto the tip of a catheter and real-time 3D optical shape sensing along its length. We expect that such smart catheter devices will disrupt the field of minimally invasive procedures. The ultimate solution will have a control loop between in-body sensing information and external imaging and therapy planning and delivery – enabled by adaptive therapy planning software.

Also in the field of cancer, that other major cause of death, we believe that much can be gained thanks to advances in imaging and genomics that are enabling precise diagnostics in an early disease stage requiring less invasive treatments. Precision diagnostics can be realized through image-guided focal biopsy, followed by molecular pathology. Image-guided targeted therapy delivery and monitoring is possible through local administration of drugs, or by precise local delivery of energy to the tumor. These procedures require, again, smaller and smarter interventional instruments that can be controlled with high level of precision, such as a photonic biopsy needles that can discriminate between tissue types or MR guided focused ultrasound treatment.

1. Quoted in E. Ridley, "Imaging poised to transform the future of medicine", *http://www.auntminnie.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=69642*
2. H. van Houten and H. Hofstraat, "Towards molecular medicine", chapter in: S. Luryi, J. M. Xu, and A. Zaslavsky, eds., *Future Trends in Microelectronics: Up the Nano Creek*, New York: Wiley, 2007, pp. 90-100.