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A look into the future of interventional radiology for the injured patient

Salvatore J.A. Sclafani *

State University of New York Downstate Medical Center, Kings County Hospital Center, United States

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On 31 August 1966 the seminal ideas that led me to focus my academic career on the treatment of traumatic conditions using miniaturised instruments opened in theatres across the United States. The movie, *Fantastic Voyage*, produced by Saul David and directed by Richard Fleischer, was a technically innovative and anatomically accurate story about the treatment of an injured scientist with knowledge critical to the maintenance of world peace and security. Injured in an attack by hostile forces, the scientist could not share this knowledge with the forces of good. The intracranial haematoma causing his coma was located in such a precarious position that surgery to remove it was thought likely to lead to his death and endanger the free world.

Scientists and physicians proposed a unique strategy to save the victim: miniaturise a nuclear powered submarine so that it and its crew, including Donald Pleasence and Racquel Welch, could be injected into the carotid artery of the victim and then voyage through the circulation into the critical area of the brain. Once at the site of the injury, the doctors would use lasers to remove the clot and thus save the patient and the free world.

The captain, played by Stephen Boyd, did a masterful job of maneuvering past eddy currents and macroproteins but the plan appeared to have failed when the submarine was rerouted from the arterial tree to the jugular vein through an arteriovenous fistula. Quick thinking allowed our heroes to traverse the right side of the heart into the lungs where they restored their depleted oxygen supply. From the lungs they traversed through the lymphatic system. Being chased by lymphocytes and other immune cells proved a daunting and tense time for the crew. Finally they reached the haematoma through the inner ear and used a laser to dissolve the blood clot. The team exited the body through a tear duct just as the miniaturisation process was reversing itself. *Fantastic Voyage* was a popular success and was nominated for five Academy Awards, winning two. It was a seminal motion picture to say the least.

This science fiction story was my earliest impetus to pursue a career as a minimally invasive endovascular interventional radiologist.

My assignment to address the future of minimally invasive therapies in the management of traumatised patients made me recall this story. My dreams of a beautiful and well-formed Ms. Welch did not hurt.

* Correspondence address: Department of Radiology, Kings County Hospital Center, 451 Clarkson Avenue, Brooklyn, NY 11203, United States. Tel.: +1 7182454447.
E-mail address: sclafans@nychhc.org.

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However, while I think miniaturisation of the physician is unlikely in the foreseeable future, the concept of miniaturisation of the tools and traversal of the vascular tree as a conduit to reach traumatised tissues for treatment is reality.

Endovascular approaches to haemorrhage control are now established firmly in the armamentarium of the traumatologist. Without randomised controlled studies, embolisation of internal iliac branches has become the treatment of choice for life threatening haemorrhage associated with pelvic fractures because it was obviously an elegant solution to a rather angry situation. The fairly routine transfusion of more than 100 U of packed red blood cells for resuscitation would no longer be acceptable and young physicians cannot even fathom such a situation. Survival can now be expected in a high percentage of these patients. These techniques were first reported for the control of renal fractures in the late 1960s when embolised surgical gelatin particles were embolised into segmental branches and to arrest haemorrhage from renal biopsies. Haemostasis by embolisation has now been reported in almost all vascular beds, Indeed traveling into the brain to close carotid artery—cavernous fistulas through orbital veins and using devices that pull emboli out of the middle cerebral artery are now mainstream so perhaps the writer, director and actors of the *Fantastic Voyage* were closer to reality than they and their audience realised. The future has arrived.

It is difficult to keep up with this future and prognostication is a difficult and moving target. In my span of a 30-year career, I have seen the development of ultrasound imaging, 3D and 4D imaging using many modalities, subtraction angiography, interventional radiology, interventional oncology, computed tomography (from stationary single slices to rows of detectors beyond 256), magnetic resonance imaging, CTA, MRA, digital radiology, PACS, teleradiology, percutaneous vascular grafting, more recently functional imaging techniques that can detect the area of the brain used for religious thought and so many more innovations. Most of it was not a consideration when I entered radiology. It is presumptuous to think that I can see the future of interventional radiology in trauma.

The treatment of the major conduits by grafting through endovascular approaches, a proposal I made in 1977 while I reviewed a case of subclavian transaction during our institution's Surgical Grand rounds, was humorously discounted at the time. The diagnostic catheter was seen on the angiogram just a centimeter from the injury and I waxed fantastically, predicting that one day that the catheter would metamorphasise into an instrument that would definitively treat such injuries. So many surgeons in the room rolled up their eyes that I thought there was a mass seizure. Now stent grafts, ePTFE covered or coated expandable stents, are routinely used to manage large vessel injuries without sacrifice or compromise of the vascular beds of those conduits. Treatment of injuries of the aorta, the brachiocephalic branches, visceral conduits, even branches we would have sacrificed by embolisation in the past, are preserved by stent grafts with good results. While randomised trials of such devices for trauma are not yet published, results are promising and I expect that they will become an accepted method of treatment in the near future.

Allow this author to look a bit into the future and share with you his fantasies of the future. While some of this may never be accepted or practiced, nothing new is inherently out of bounds. I ask you not to roll your eyes.

Firstly I think that the use of the minimally invasive catheter to evaluate and diagnose injuries will soon play a lesser role. I have no doubt that non-invasive techniques of vascular imaging will replace angiography for most injuries. While I do not think that the data yet support CT angiography, MR Angiography and ultrasound as the gold standards of vascular diagnosis, their day will surely come in the near future. Improvements in technology, better understanding of the appearance of injuries, establishment of standard methods of acquiring data will make these modalities faster, more readily available, more easily viewed and interpreted. No longer will we have to wait for a procedure team to assemble. A radiologist, or should I say an imager, located hundreds or thousands of miles away, will sit at a console displaying images from multiple trauma centres. The acquired data set of transmitted images will be automatically displayed in multiple projections, allowing an analysis of the wall, the lumen and surrounding structures. The rendered images will be sent back to the treating physician's portable computer, PDA or heads up display. The virtual radiologist will review and point out the findings on the physician's image review station as he walks through the hospital. A pleasantry exchanged, they will both go back to their business.

But imaging will have its own fantastic voyage as we move our view from gross architectural derangements to cellular dysfunction. Molecular imaging will one day tell us the status of the interior of the cell. Will ''ruffled'' intima contain apoptotic cells? When will endothelial regrowth be completed? Can we identify damaged cells that can be salvaged? Can we define dead cells that need be removed or replaced? Will the ability to see on this level change our treatment perspectives? I