DOTmed News - Michael Friebe on contrast media injection – we need it, but we don’t like it!

Michael Friebe, PhD
March 21, 2016
By: Michael Friebe

Injectors are used for X-ray procedures (mainly in the cath and angio labs), for diagnostic imaging using tomography systems (CT, MRI, hybrid imaging systems like PET/CT or MR/PET) and for use in contrast-enhanced ultrasound (CEUS) examinations. The medical need for contrast media in the enhancement of the diagnostic images is not in question, but the application of the contrast media into the blood stream is not without danger for the patient, and requires a great deal of experience and training for the operators of the injector systems.

Contrast media injection is generally realized by using power injectors, mainly electromechanical or hydraulic piston or peristaltic drives, with two different injection volumes (syringes, bags or bottles) with the first one, saline, having the task of opening the vein for the second one that injects the contrast media. This is then followed by a flush from the first, thereby again reducing the total contrast media consumption and increasing patient safety through reduced flow rates. Fast imaging, as in multi-slice detector CT imaging or high-field MRI, requires dual volume injector systems.

There are issues with the consumables that are required for the injection, including tubing and syringes, the actual injection pathway, use of the controlling computer system, hardware (batteries, magnetic attraction when used in an MRI suite, servicing, electric safety), variables of the injection (amount of contrast media, timing, injection rate), patient safety and the use of varying injection protocols.

Injector systems are relatively large and complex and need some time for patient setup, all for an apparently easy task of injecting a liquid into the patient's bloodstream at the right point in time with respect to the imaging procedure. Increased complexity means decreased patient safety and usually also comes with increased investment and operational cost. The question is whether they really need to be that complex. So what is really needed, what is nice to have and what are the features that a standard user can do without?

The focus of this story is on electromechanical CT and MRI injectors and on intravenous or intra-arterial injections, but many of the issues also apply to the injection systems used for X-ray and U.S. applications. A medium-sized hospital can easily own and operate 25 of these injectors with an average operational time before replacement of seven to eight years, and an investment from $10,000 (single syringe) to $40,000 (multiphase, multi-contrast media).

In general these systems are quite reliable, but require at least an annual maintenance and safety check, and in case of high utilization, a service every six months. The cost for these service procedures is typically between $500 and $1,500.

More of a problem is the consumables that are required for the different injector systems. Some use syringes with recommended single use that are very often only replaced once a day. However, others use bottles or bags that can contain larger amounts of contrast media and do not need to be replaced for every patient. Tubing from the syringe/ bag to the patient obviously needs to be replaced with every patient and the total cost per patient can run from $5 to $25, plus the cost of the contrast media. Investment as well as operational cost in combination with the required individual patient setup time is certainly something that needs to be taken into consideration when selecting an injector.

For CT injection protocols, timing is essential to achieve the desired contrast. A relatively standard volume is between 75ml and 150ml, depending on patient weight, iodine-based contrast media using an injection rate of typically between 3-5ml/s (using a 20-gauge flexible plastic cannula). The injection protocol also needs to be adapted to the type of CT scanner used (number of slices) and is complemented with the injection of saline solution which requires two working channels as a syringe or bag system. Timing of injection is critical with respect to the CT imaging and a computer control is therefore essential.

Typical MRI contrast media injection (gadolinium-based, which shortens the T1 relaxation time) is administered as a rapid intravenous bolus, depending on weight (approximately 0.2ml/kg) at a flow rate of 2ml/s. For a 100kg (220-pound) patient approximately 20ml of contrast media is used that is subsequently flushed with 20ml of saline solution at the same injection rate. Approximately 30 seconds after that the MRI imaging protocols start. The peak enhancement is about 2 minutes after injection and holds on for several minutes. The standard MRI contrast media injection protocol is relatively simple, and the injector would theoretically only require one or two different flow rates and simple timers for 90 percent of all applications.

Technically the injectors only require a driving unit that is capable of injection at a flow rate of 2ml/s (MRI) or 4ml/s (CT); a volume of 20ml (typical MRI) to 150ml (CT) contrast media with injection of saline solution before and immediately following the contrast media injection. There are some rarely-used advanced protocols that require multiphase injections and varying flow rates, but with the above minimum specification a large majority of the normal contrast media imaging could be accomplished. The currently available injectors can do significantly more than is required for these standard injection

protocols. Easier, less costly and less complex solutions could be developed, especially for use in the MRI suite, where plastics and avoidance of electronic systems/components are also solving the problem of MRI compatibility/safety.

What is required from a patient safety point of view? Consider the following:

• Ease of use and low complexity are key elements of patient safety. If there are only a few variables and components, the user training is fast and the error margin low.
• “Open” contrast media and saline volumes should not be used to prevent infections, sepsis and contaminations.
• Standard (and easy) operating procedures for injection should be in place to avoid extravasation and air emboli.
• Some injector systems on the market offer optional extravasation protection (through sensors that measure variances in skin surface or RFID signals).
• All procedures should allow for the removal of any air in the tubing by rotating the injector head and slowly pushing liquid into the tubing with an optional air bubble detection sensor.
• Injector systems should include sensors and safety measures if an overpressure occurs.
• Optional sensors for contrast leaks could be helpful.
• Some vendors now offer RFID identifiers that prevent using single-use syringes more than once.
• Equipment should allow for the possibility to recall some forensic data such as the amount of contrast media injected with what parameters at what time.

Other features not directly patient safety- related that are optionally offered are RIS/data management systems connections and network integrations that allow for the measurement of workflow efficiency and imaging optimization. This also allows management of injector service issues and can track historical use of contrast media with respect to patients, diseases and imaging protocols.

The syringes (single or multi-use) and their cost — but also patient safety issues related to multi-use — are definitely quite an important consideration. Especially in the U.S., pre-filled syringes are getting more popular while other vendors are betting on larger volume bottles that reduce the preparation time and the cost of the consumables. Dual flow allows the parallel injection of contrast media and saline solution, and with that could help to provide new or enhanced contrast particularly for cardiac imaging.

Contrast media viscosity is temperature dependent, as a warmer application temperature decreases the viscosity and flow resistance. Warming the contrast media before injection is therefore beneficial, and some injectors have such a feature built into the system.

Another hardware aspect is the power source and weight of the injector systems. While most CT injectors are directly connected to a power outlet (weight between 5kg and 25kg), MRI injectors (weight 10kg to 35kg) usually have a battery integrated that has a tendency to be empty every once

in a while when you really need it. Alternative solutions are hydraulic-driven systems or almost entirely mechanical systems with a small battery backup of injection information and control of safety features. Especially for use in the MRI suite, electronic and metallic components are a potential safety and operational hazard and for ultimate patient safety the device should be lightweight and manufactured from nonferromagnetic materials with little to no electronic components,

Dual volume injectors are needed, and a large majority of the CT and MRI injection protocols are standard with respect to flow rate, while the injection volume is weight dependent. Most systems on the market can offer a lot more than these standard protocols, which also translates into high cost for investment and operation (service costs, consumables). Patient safety should be a key concern, which also determines the must haves, should haves, nice to haves and not needed as summarized in the chart that accompanies this story.

Michael Friebe is a professor of catheter technologies and image- guided therapies at Otto-von-Guericke University in Magdeburg, Germany.

More People & Company Headlines