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This quarterly supplement to *Applied Radiology* confers 0.5 ARRT Category A Continuing Education credits, which will be awarded upon completion of an online post test. The entire text of this supplement and the post test are available at www.appliedradiology.com/contrast.

This supplement and the ensuing post test are designed to be completed within 30 minutes. The goal is to provide an overview of the type of data that can be collected via a CT power injector and how it can be used to affect image quality, cost-efficiency and patient safety.

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Using Injector Data to Improve Quality, Cost Efficiency and Safety

Kathleen Dallessio

In today's economic climate, efficiency is essential. For imaging departments, this means continually devising methods to contain cost, optimize workflow and increase patient safety, all while working to maintain high-quality diagnostic imaging services. To achieve these goals, imaging professionals must rely on concise and accurate data to assess the practices within the imaging suite.

When it comes to contrast-enhanced computed tomography (CT) studies, particularly those in which a power-injector system is used, there is a plethora of data that can be mined to assess quality and efficiency. Assembling the data into a central repository, however, has not always been easy.

Typically with power-injected contrast-enhanced CT studies, the data associated with the study, such as patient demographics, contrast volume, flow rate, protocol parameters, and other important information, may be spread out across the injector, the scanner, and/or the patient record, or not stored at all. This can make data retrieval difficult, if not impossible.

Putting it all together

Recently Stanford University Medical Center in Palo Atlo, CA, began using the IRiSCT Injector Reporting Information System in conjunction with their ACIST EmpowerCTA injectors from ACIST Medical Systems Inc., A Bracco Group Co. (Eden Prairie, MN) to help gather and store all essential contrast-related data. This system allows the department's scanners, injectors, and networks to more easily share essential clinical data (Table 1), and store it within a single system.

"Six of our different CT scanners are connected with the power injectors," said Lior Molvin, RT(R)(CT), CT Protocol Technologist at Stanford. "What IRiSCT allows us to do is to gather contrast injection information and route it to a main server. Then we can either look at the IRiSCT management application on the individual injector, or all of the injectors, or on the main server"

Because IRiSCT is based on a Windows® platform, the data can be automatically loaded into any Windows database program such as Microsoft Excel or Microsoft Access for report generation. At Stanford, Molvin uses the data to produce quarterly utilization reports.

"I've come to rely on the quantifiable, objective information I'm receiving," Molvin said. "I am creating reports and sharing them with our managers. We decided to do this quarterly because we can match these reports with our quarterly budget plans, allowing us to better assess contrast utilization and waste."

Reducing waste

These IRiSCT reports, detail a variety of factors, including the number of syringes used and the amount of contrast loaded for each study, as well as the amount of contrast used and how much was left over.

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"Residual contrast is a very important number for us," Molvin said. The reports also allow him to look for trends. "We find trends between the different scanners. The reports reveal the variations among our technologists, the different shifts, how they approach the injector, and how they use it for the scan. In terms of cost utilization and waste trends, there definitely are patterns to busy and slower quarters. This information can then be used to optimize purchasing decisions."

Improving quality

The data is also used in the quality assurance (QA) process.

"Anytime a physician reports a QA problem, we can turn to the data to determine what went wrong with the injection that led to the suboptimal image quality.," Molvin said.

Anytime a physician reports a QA problem, we can turn to the data to determine what went wrong

If there was a problem with a scan in the past, he may have been able to gather the scan parameters from the scanner, but the injector data would not have been recoverable.

"We can always look back at a CT scan and dial down the scan parameters and find out exactly what went wrong in terms of timing, but in the picture archiving and communications system (PACS), it has been very hard to figure out what went wrong with the injection," Molvin said. "The IRiSCT allows us to uncover, for example, the maximum PSI reached. Many times when you have a power injector, if the maximum PSI is lowered, it will never reach the flow rate (e.g. mL/sec) specified in the protocol and entered by the technologist."

With the data from theIRiSCT, the staff at Stanford University Medical Center is able to clearly see these types of events.

Improving patient safety

With any contrast injection, and particularly with the use of power injectors, clinicians must always be mindful of the risk of extravasation. There is a correlation between injection rate and catheter size and the amount of pressure applied to the IV.

At Stanford, technologists monitor for extravasation manually and use the system to monitor the pressure at the exact time of injection.

"We can watch as the pressure goes from 40 to 50 to 60 PSI and back down to 50 PSI," Molvin said. "If necessary, we are then able to increase the injection rate once we see that the PSI has reached a steady, low level."

In addition, the system can automatically convert creatinine into glomerular filtration rates (GFR) with a built-in GFR calculator. The glomerular filtration rate is a description of the flow rate of filtered fluid through the kidney. While serum creatinine (SCr) is the generally accepted measure of renal function, and thus the determinant of who receives contrast-enhanced CT, there has been a growing shift to using the Modification of Diet in Renal Disease (MDRD) formula, which estimates GFR.[1] An online calculator tool is available at: http://nephron.com/cgibin/MDRDSIdefault.cgi. Using this equation, general risk thresholds have been established for patients. GFR values are thought to be more fine-tuned since they also account for gender and race, with specific equations for women and people who are African-American. Having the ability to calculate GFR on the injector can speed up a workflow step without compromising safety.

"You can actually convert a creatinine into a GFR on the injector," said Molvin. "It is very easy to use and helpful, particularly when a patient has borderline renal function. If you type in a creatinine or a GFR, it will be calculated for you, it will be attached to that injection, and then you can go back and look in the log to see what happened. For instance, a person with a creatinine of 1.5 mg/dL, which is borderline, could have a GFR that ranges from 30 to more than 100 mL/min. For example, a 25-year-old male athlete with a creatinine of 1.5 mg/dL would have a GFR of 133. If you had that same creatinine in a 90-year-old male, the GFR would probably be about 58. The old measure of renal function through serum creatinine does not describe the patient as accurately as GFR."

Estimating risk of CIN

GFR and serum creatinine calculations are collected in order to prevent instances of contrast induced nephropathy (CIN). Generally patients at greatest risk for CIN are those who have an SCr ≥1.5 mg/dL, those who have pre-existing renal insufficiency, diabetes mellitus, those who are dehydrated, those with cardiovascular disease and who use diuretics, patients older than 70 years, and those with myeloma, hypertension, and hyperuricemia.[2]

Most of the literature points to renal insufficiency as the most significant risk factor for CIN. However, the rate of CIN for CT procedures in patients with renal insufficiency is only about 5% of all CT studies.[3] At worst, CIN incurred as a result of a contrast-enhanced CT study could cause permanent renal injury. Most importantly, adequate hydration is the only universally accepted prophylactic measure for CIN.[3] It is important for CT departments to be especially careful in evaluating patients since, oftentimes, instances of CIN will go undetected until the patient returns home or is followed-up for further medical evaluation.

A recent study indicated that acute kidney injury as a result of CIN could be linked to serious long-term adverse events such as death, heart attack and stroke.[4] However, the article failed to demonstrate a clear causal relationship between contrast material and CIN and the related adverse events.

References

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2. Byrd L, Sherman RL. Radiocontrast-induced acute renal failure: A clinical and pathophysiologic review. *Medicine.* 1979;58:270-279.
3. Katzberg, RW. Contrast-induced nephropathy in 2010. Applied Radiology. 2010;39(9):21-23.
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Table 1. Data collected using the IRiSCT System.

- Contrast flow rate
- Contrast volume
- Total contrast filled
- Contrast used
- Contrast wasted
- Average PSI
- Maximum PSI
- Saline volume and flow rate on dual head injectors
- Extravasation detection accessory (EDA) system activation status*
- Number of EDA-identified extravasations*

*When used with the EDA optional feature

Using Data to Optimizing Image Quality and Scanning Protocols: A Physician's Perspective

When performing contrast-enhanced computed tomography (CT) with power-injection systems, a wealth of data is generated regarding the injection. Gathering and storing this information in an easily accessible format allows radiologists to use the data to improve image quality and scanning protocols and, by extension, improve both efficiency and patient safety.

Monitoring protocols

"The main purpose of gathering and storing the data is to optimize injection protocols and to monitor how well those protocols work," said Dominik Fleischmann, MD, Associate Professor of Radiology, Department of Radiology at Stanford University Medical Center, Palo Alto, CA.

At Stanford, the imaging department uses the IRiSCT Injector Reporting Information System in conjunction with ACIST EmpowerCTA injectors from ACIST Medical Systems Inc., A Bracco Group Co. (Eden Prairie, MN) to assemble and store injection-related data. One of the key uses of this data is to watch for potential problems or trends.

"It is really a tool to get quantitative information on what was injected," Dr. Fleischmann said. "If we observe a series of suboptimal opacifications with a specific protocol, then we might change the protocol. For example, if we observe that the opacification is not what we would like in a pulmonary embolism study, then we would know that the injection protocol that we used is probably not optimal and we would need to revisit that."

Peak opacification has been measured in several ways but generally the best utilization of contrast is timed so that the bolus reaches the target organ or artery at its peak opacification, respective to the CT scanner technology. This is a challenge as faster CT scanners with more detectors and slices can very easily outrun the bolus. Most CT injection protocols employ some type of scan delay with automatic bolus triggering. It has also been shown that the time to peak opacification can vary significantly based on a wide variety of factors, such as patient weight, target organ, IV catheter size, injection velocity, pressure, fluid viscosity and even the injection site (e.g., antecubital, forearm, wrist, and hand).

Feedback loop

The data collected by the IRiSCT reporting system is also helpful when there is a change in the scanner hardware or software.

"Usually we are aware of the fact that our protocols must change commensurate with improvements in scanner technology," said Dr. Fleischmann. "We have a total of 7 scanners and our scanners are replaced or updated occasionally; besides complete new hardware installs, software updates can also affect the scanner's speed. You always need to review and potentially adjust the protocols. That is why you want to have a feedback loop about how the image quality is affected."

Quality assurance

With contrast-enhanced CT, there are many potential sources of error. In the past it has been difficult to identify the cause.

"When a suboptimal scan was generated, it was never easy to determine what was specifically wrong with the procedure," Dr. Fleischmann said. "You could try to reconstruct the effects but that is, of course, not reliable. You want to have documentation of what happened. If you want to examine what was actually injected, then you need that information to be very well documented. That is what we get from the IRiSCT."

With this system, the data is available right in the reading room to help the radiologist reconstruct exactly what happened during the injection and scan.

"Usually we go back and use the information if we see something unexpected," Dr. Fleischmann said. "For example, if the opacification is not as good as we thought, then we can look at the injector and see if there was a malfunction or see if there was less contrast injected than we thought. For example, if the injector down-regulates the injection because the injection pressure was exceeded, then those are all things that one can see on the IRiSCT system."

Research applications

Precise and accurate data is essential when developing new protocols and guidelines.

"If you want to develop your own guidelines concerning which IV lines or central lines to use with power injection, you can test power injectors with different catheters and collect the information regarding the pressure that it generates directly from the injector," Dr. Fleischmann said. "You can use IRiSCT to document the pressure in the system."

With that level of detailed data, radiologists can compare images from different combinations and determine optimal parameters.

Pumps with computers

The bottom line for modern power injectors — and this is very general — is that they are all computers, according to Dr. Fleischmann.

"In the past they were just pumps," he said. "Now they are pumps with computers. Because all these computers control the injectors, they also generate this data. So I think that this technology is taking advantage of the information that is available."

Quiz

Post your quiz answers to appliedradiology.com/contrast to receive your CE certificate for this activity. Opt-in to receive a digital version of the next 2 supplements in this series and you will be automatically entered into a raffle for an Apple iPad®!

1. Glomerular filtration rate (GFR) values take into account:
   A. Patient weight
   B. Patient Race
   C. Patient BMI
   D. None of the above

2. Patients with a serum creatinine value of _____ are not recommended to receive contrast-enhanced studies.
   A. ≥0.4 mg/dL
   B. ≤0.4 mg/dL
   C. ≥1.5 mg/dL
   D. ≥3.0 mg/dL

3. The risk of contrast induced nephropathy is deemed to be:
   A. 2%
   B. 3%
   C. 4%
   D. 5%

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4. Which of these is not one of the adverse events linked to CIN-related acute kidney injury:
   A. Stroke
   B. Heart attack
   C. Muscular dystrophy
   D. Death

5. The estimated glomerular filtration rate uses a mathematical formula to describe the flow rate of filtered fluid through the kidney.
   A. True
   B. False

6. Which of these patients is NOT at risk for CIN?
   A. Those older than 35 years
   B. Those with an SCr ≥1.5 mg/dL
   C. Those with pre-existing renal insufficiency
   D. Patients with cardiovascular disease and who use diuretics

7. Hydration is not a commonly accepted prophylactic measure to alleviate the instances of CIN.
   A. True
   B. False

8. Which of these data points can NOT be collected on a computerized CT power injector information system?
   A. Contrast flow rate
   B. Contrast volume
   C. Contrast used
   D. CTDI^{vol}

9. Which of the following is most likely to contribute to suboptimal opacification?
   A. Low injection pressure below prescribed protocol value
   B. Timing the bolus by using a scan delay specific to the CT scanner technology
   C. Insufficient number of slices/detectors
   D. Reducing the amount of contrast used

10. Which of the following can affect the time to peak opacification?
    A. Patient weight
    B. injection velocity
    C. Injection pressure
    D. All of the above