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Review Article

CONTRAST MEDIA USED IN COMPUTED TOMOGRAPHY

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Abstract: Contrast media (CM) are used in imaging techniques to enhance the differences between body tissues on images. The ideal contrast medium should attain a very high concentration in the tissues without producing any adverse effects. Unfortunately, this has not been possible so far and all CM have adverse effects. The increasing use of CM is likely to give rise to a wide range of pitfalls, including compliance with and appropriateness of indications for the use of CM themselves, the choice of the 'best' contrast agent, off-label use, evaluation of special populations of patients. Even more prominently it is the issue of informed consent which brings with it a duty to inform patients awaiting the administration of CM with regard to the nature of the procedure, the existence of alternative procedures, the extent of the risks relating to the use of CM and, finally, the risks relating to refusal of the procedure. All these issues may give rise to concerns about liability for failure to offer adequate information to patients or to carefully evaluate and balance the potential risks and benefits of the procedure or, finally, for being unprepared in the event of adverse reactions to CM, especially when these are severe and life-threatening. Educational and training programmes for radiologists are likely to shape change in the medical liability environment in the coming years.

Keywords: Contrast media (CM), Computed Tomography, Radiocontrast Agents, Magnetic resonance imaging (MRI)

Introduction: Contrast media (CM) enhance the quality of images, revolutionizing the radiologist's ability to differentiate soft-tissue densities. Half of the approximately 76 million computed tomographic and 34 million magnetic resonance imaging examinations performed each year include the use of intravenous contrast agents. Many advanced clinical imaging applications were developed and refined with the use of intravenous contrast agents[1]. Ideally, contrast agents should be injected and eliminated from the body without additional effects on the patient. Ideally, CM should attain

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a very high concentration in the tissues without producing any adverse effects. Unfortunately this has not been possible so far and all CM have adverse effects.

Radiocontrast agents are substances used to enhance the visibility of internal structures in X-ray-based imaging techniques such as computed tomography (contrast CT), projectional radiography, and fluoroscopy. Radiocontrast agents are typically iodine, barium-sulphate or gadolinium based compounds. They absorb external X-rays, resulting in decreased exposure on the X-ray detector. This is different from radiopharmaceuticals used in nuclear medicine which emit radiation[1].

Magnetic resonance imaging (MRI) functions through different principles and thus utilizes different contrast agents. These compounds work by altering the magnetic properties of nearby hydrogen nuclei. Although the currently available contrast agents generally are considered to be safe, their use is not completely without risk. Adverse effects vary from minor physiologic and mild allergic-like reactions to rare but severe and life-threatening events. Although the prevalence of these reactions is low for both CT and MR imaging, reactions to contrast media do occur, and rapid evaluation and treatment of them requires designated and well-trained personnel and appropriate, readily available equipment and medications. Ideally, identification of patients likely to experience adverse effects with contrast agents should occur before approval and completion of these examinations. When an adverse event arises, knowledge of the types of reactions that manifest and prompt treatment are critical, and therefore, appropriate training must be provided to all individuals involved in administration of contrast material. In the last few years, procedures employing CM have tremendously increased[2].

Contrast materials, also called contrast agents or contrast media, are used to improve pictures of the inside of the body produced by x-rays, computed tomography (CT), magnetic resonance (MR) imaging, and ultrasound. Often, contrast materials allow the radiologist to distinguish normal from abnormal conditions. Contrast materials are not dyes that permanently discolor internal organs[2]. They are substances that temporarily change the way x-rays or other imaging tools interact with the body.

When introduced into the body prior to an imaging exam, contrast materials make certain structures or tissues in the body appear different on the images than they would if no contrast material had been administered. Contrast materials help distinguish or “contrast” selected areas of the body from surrounding tissue. By improving the visibility of specific organs, blood vessels or tissues, contrast materials help physicians diagnose medical conditions.

Types of Contrast Agents used in CT

There are four types of contrast agent used in CT:

1. The type that is given via intravenous (through a vein) injection
2. The type that is given orally
3. The type that is given rectally
4. A much less common type of contrast used in CT is inhaled as a gas and used for special lung and brain imaging. This technique (called Xenon CT) is only available at a small number of locations throughout the world and is only performed for rare cases.

CT Contrast Given Via Intravenous Injection: Intravenous contrast is used in CT to help highlight blood vessels and to enhance the tissue structure of various organs such as the brain, spine, liver and kidneys. "Intravenous" means that the contrast is injected into a vein using a small needle. Some imaging exams of the abdomen and gastrointestinal system use both the intravenous iodine and orally administered barium contrast for maximum sensitivity.

The intravenous CT contrast is clear like water and has a similar consistency. It is typically packaged in glass bottle or vial. A sterile syringe is used to draw it from the bottle or a power injector is used to administer the contrast. Typically between 75 cc to 150 cc (about 2.5 oz. to 5 oz) of contrast is used depending upon the patient's age, weight, area being imaged and cardiovascular health[3].

How does Intravenous CT Contrast Work?

A small needle is first placed into a vein in the hand or arm by the radiologist, technologist or a nurse and held in place with tape or a strap. Once the needle is in place, the vein is flushed with saline solution. Typically the contrast is loaded into a power-assisted injector, which injects the CT contrast using tubing through the needle into the body during a specific period in the CT exam. The injection is fully under the control of the technologist or radiologist. The injector is either mounted on a small trolley or hung from a ceiling mounted suspension next to the CT scanner. The contrast may also be hand injected using a large syringe connected to the needle via tubing.

Once the iodine contrast has been injected into the blood stream, it circulates through the heart and passes into the arteries, through the body's capillaries and then into the veins and back to the heart. As CT images are being acquired, the CT's x-ray beam is attenuated (weakened) as they pass through the blood vessels and organs flush with the contrast. This causes the blood vessels and organs filled with the contrast to "enhance" and show up as white areas on the x-ray or CT images. The kidneys and liver eliminate the contrast from the blood.

What Preparation is Needed Before Receiving Intravenous Contrast?

Sometimes it is necessary to not drink anything for an hour to several hours before the exam. The preparation time varies depending on the actual exam as well as the imaging center's requirements. Always ask the staff where the exam is scheduled for exact guidelines.

Is Intravenous CT Contrast Safe?

Typically, a patient will be asked to sign an "informed consent form" prior to having an CT exam which uses iodine contrast. This form will outline the potential side effects of the iodine. Overall, iodine is safe and has been used for many years and in millions of x-ray, CT and angiogram studies without serious side effects. Iodine contrast increases the sensitivity of the CT study. Thus the benefits of using iodine contrast typically outweigh the risks. Patients should inform the radiologist or technologist if they have a history of allergies (especially to medications, previous iodine injections, or shellfish), diabetes, asthma, a heart condition, kidney problems, or thyroid conditions. These conditions may indicate a higher risk of iodine reactions or problems with eliminating the iodine after the exam[4].

Oral CT Contrast: It is important that patients consult the imaging location performing their CT exam for specific instructions to follow when contrast will be used. The information contained herein is only a general guideline. Oral contrast is often used to enhance CT images of the abdomen and pelvis. There are two different types of substances used for oral CT contrast. The first, barium sulfate, is the most common oral contrast agent used in CT. The second type of contrast agent is sometimes used as a substitute for barium and is called Gastrografin.

Barium contrast looks like and has a similar consistency as a milk shake. It is mixed with water and depending on the brand used, may have different flavors (for example, strawberry or lemon). Gastrografin contrast is a water-based drink mixed with iodine and has a tinted yellow color. When given orally, gastrografin may taste bitter. Patients usually need to drink at least 1000 to 1500 cc (about three to four 12 oz. drinks) to sufficiently fill the stomach and intestines with oral contrast.

Which imaging exams use contrast materials?

Oral Contrast Materials: Barium-sulfate contrast materials that are swallowed or administered by mouth (orally) are used to enhance x-ray and CT images of the gastrointestinal (GI) tract, including:

- pharynx

- esophagus
- stomach
- the small intestine
- the large intestine (colon)

In some situations, iodine-based contrast materials are substituted for barium-sulfate contrast materials for oral administration.

Rectal Contrast Materials

Barium-sulfate contrast materials that are administered by enema (rectally) are used to enhance x-ray and CT images of the lower gastrointestinal (GI) tract (colon and rectum). In some situations, iodine-based contrast materials are substituted for barium-sulfate contrast materials for rectal administration[3].

Intravenous Contrast Materials

Iodine-based and Gadolinium-based: Iodine-based contrast materials injected into a vein (intravenously) are used to enhance x-ray and CT images. Gadolinium injected into a vein (intravenously) is used to enhance MR images. Typically they are used to enhance the:

- internal organs, including the heart, lungs, liver, adrenal glands, kidneys, pancreas, gallbladder, spleen, uterus, and bladder
- gastrointestinal tract, including the stomach, small intestine and large intestine
- arteries and veins of the body, including vessels in the brain, neck, chest, abdomen, pelvis and legs
- soft tissues of the body, including the muscles, fat and skin
- brain
- breast

Microbubble Contrast Materials: Microbubble contrast materials are tiny bubbles of an injectable gas held in a supporting shell. They are extremely small —smaller than a red blood cell— and have a high degree of "echogenicity", or ability to reflect ultrasound waves. Structures with higher echogenicity will appear brighter on ultrasound. Once the microbubbles are in the bloodstream, ultrasound technology is able capture differences in echogenicity between the gas in the microbubbles and the surrounding tissues of the body, producing a sonogram with increased contrast. The microbubbles dissolve, usually within 10 to 15 minutes, and the gas within them is removed from the body through exhalation. Contrast-enhanced ultrasound with microbubbles is a convenient, relatively inexpensive way to improve visualization of blood flow that does not use radiation. It is a useful option for patients with kidney failure or allergies to MRI and/or computed tomography (CT) contrast material.

Contrast-enhanced ultrasound with microbubbles is used in the assessment of:

- blood perfusion in organs
- thrombosis, such as in myocardial infarction
- abnormalities in the heart
- liver and kidney masses
- inflammatory activity in inflammatory bowel disease
- chemotherapy treatment response

Side effects and adverse and allergic reactions

Barium Sulfate Contrast Materials

You should tell your doctor if these mild side effects of barium-sulfate contrast materials become severe or do not go away:

- stomach cramps
- diarrhea
- nausea
- vomiting
- constipation

Contrast-Induced Nephropathy: Patients with impaired kidney (renal) function should be given special consideration before receiving iodine-based contrast materials by vein or artery. Such patients are at risk for developing contrast-induced nephropathy, in which the pre-existing kidney damage is worsened.

At-Risk Patients: Some conditions increase the risk of an allergic or adverse reaction to iodine-based contrast materials. These include:

- previous adverse reactions to iodine-based contrast materials
- history of asthma
- history of allergy
- heart disease

- dehydration
- sickle cell anemia, polycythemia and myeloma
- renal disease
- the use of medications such as Beta blockers, NSAIDs, interleukin 2
- having received a large amount of contrast material within the past 24 hours

Being at increased risk for an allergic or adverse reaction to contrast material does not necessarily mean a patient cannot undergo an imaging exam with contrast materials. Medications are sometimes given before the contrast material is administered to lessen the risk of an allergic reaction in susceptible patients.

MR-Gadolinium: The contrast material used in MR called gadolinium is less likely to produce an allergic reaction than the iodine-based materials used for x-rays and CT scanning. Very rarely, patients are allergic to gadolinium-based contrast materials and experience hives and itchy eyes. Reactions usually are mild and easily controlled by medication. Severe reactions are rare. Nephrogenic systemic fibrosis (NSF), a thickening of the skin, organs and other tissues, is a rare complication in patients with kidney disease that undergo an MR with contrast material. Gadolinium-based contrast material may be withheld in some patients with severe kidney disease[5].

Pregnancy and contrast materials: Prior to any imaging exam, women should always inform their physician or x-ray technologist if there is any possibility that they are pregnant. Many imaging tests and contrast material administrations are avoided during pregnancy to minimize risk to the baby. For CT imaging, if a pregnant woman must undergo imaging with an iodine-based contrast material, the patient should have a discussion with her referring physician and radiologist to understand the potential risks and benefits of the contrast-enhanced scan. For MR imaging, gadolinium contrast material administration is usually avoided due to unknown risk to the baby, but may be used when critical information must be obtained that is only available with the use of gadolinium-based contrast material[5].

Intravenous Contrast Material (Iodine and Gadolinium) and Breast-feeding: Manufacturers of intravenous contrast indicate mothers should not breast-feed their babies for 24 to 48 hours after contrast medium is given. However, both the American College of Radiology (ACR) and the European Society of Urogenital Radiology note that the available data suggest that it is safe to continue breast-feeding after receiving intravenous contrast. The Manual on Contrast Media from the ACR states:

If the mother remains concerned about any potential ill effects, she should be given the opportunity to make an informed decision as to whether to continue or temporarily abstain from breast-feeding after receiving a gadolinium contrast medium. If the mother so desires, she may abstain from breast-feeding for 24 hours with active expression and discarding of breast milk from both breasts during that period. In anticipation of this, she may wish to use a breast pump to obtain milk before the contrast study to feed the infant during the 24-hour period following the examination."

Discontinued agents

Nonsoluble substances

In the past, some non water-soluble contrast agents were used. One such substance was iofendylate which was an iodinated oil-based substance that was commonly used in myelography. Due to it being oil-based, it was recommended that the physician remove it from the patient at the end of the procedure. This was a painful and difficult step and because complete removal could not always be achieved, iofendylate's persistence in the body might sometimes lead to arachnoiditis, a potentially painful and debilitating lifelong disorder of the spine. Iofendylate's use ceased when water-soluble agents became available in the late 1970s. Also, with the advent of MRI, myelography became much less-commonly performed.

Adverse Effects

Contrast induced nephropathy: Iodinated contrast may be toxic to the kidneys, especially when given via the arteries prior to studies such as catheter coronary angiography. Non-ionic contrast agents, which are almost exclusively used in computed tomography studies, have not been shown to cause CIN when given intravenously at doses needed for CT studies[6].

Thyroid dysfunction: Iodinated radio contrast can induce over activity (hyperthyroidism) and underactivity of the thyroid gland. The risk of either condition developing after a single examination is 2-3 times that those who have not undergone a scan with iodinated contrast. Thyroid underactivity is mediated by a phenomenon called the Wolff–Chaikoff effect where iodine suppresses the production of thyroid hormones; this is usually temporary but there is an association with longer-term thyroid underactivity[7].

Conclusion: The increasing use of CM is likely to give rise to a wide range of pitfalls, from compliance with and appropriateness of indications, to the choice of the 'best' contrast agent. Moreover, off-label use, evaluation of special populations of patients, and readiness to deal with emergency scenarios following the administration of CM are some of the most challenging issues for radiologists. Even more prominent, and potentially more important, is the issue of informed consent which implies a duty to inform patients awaiting the administration of CM of the nature of the procedure, the existence of alternative procedures, the extent of the risks related to their use and, finally, the risks of refusing the procedure.

All the above-mentioned issues may give rise to concerns about liability for failure to offer adequate information to patients or to carefully evaluate and balance the potential risks and benefits of the procedure or, finally, for being unprepared in the event of adverse reactions to CM, especially when severe and life-threatening. Educational and training programmes for radiologists are likely to shape change in the medical liability environment in the years to come.

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