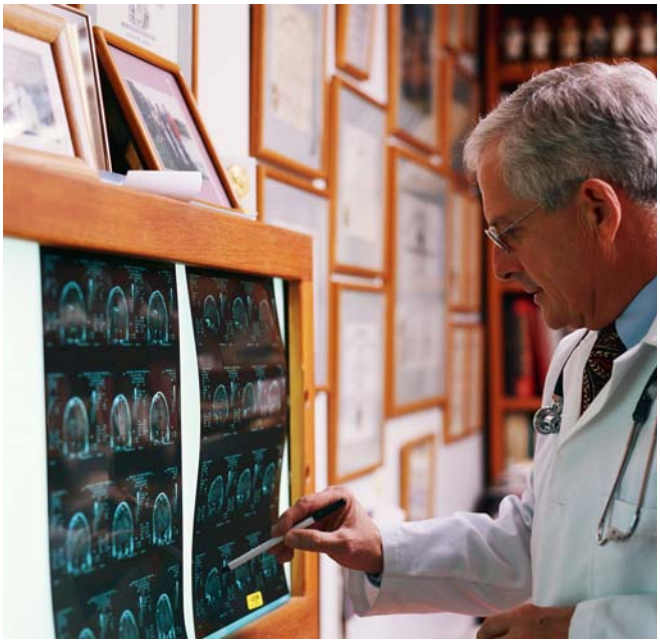
TCHP Education Consortium

Everything You Need to Know About MRI Scanning



A home study program from the TCHP Education Consortium

Introduction

MRI scanning – we've all heard about it, some of us have been there for patients, some of us have even had MRI scanning done. But what is it really? Who benefits from MRI scanning? Who shouldn't have it done? And how can we ensure the safety of our patients and ourselves while utilizing this resource safely? The purpose of this home study is to find out the answers to these questions and more!

Objectives

After reviewing this home study program, you will be able to:

1) Describe how an MRI obtains tissue images.
2) Identify safe and unsafe items the magnet room.
3) Identify the patient safety concerns related to MRI scanning.
4) Describe the preparation of the patient and procedure for an MRI scan.

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As required by ANCC, this continuing education activity must carry an expiration date. The last day that post tests will be accepted for this edition is **December 31, 2018**—your envelope must be postmarked on or before that day.

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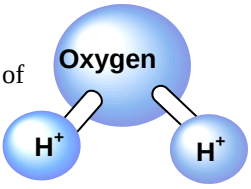
Please see the last page of the packet before the post-test for information on submitting your post-test and evaluation for contact hours.

The first section of this program explains the physics and inner workings of the MRI scanner. Some of you will be very interested in this; for others, this may seem quite technical. After this section, patient care and safety issues are addressed.

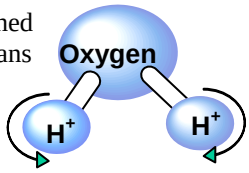
What is an MRI and how does it work?

MRI – *magnetic resonance imaging* – is a diagnostic modality that is growing in usage almost daily. The MRI uses a strong magnetic field, radio frequencies and gradients to take images of the body. It concentrates on two major constituents of the body: water and fat.

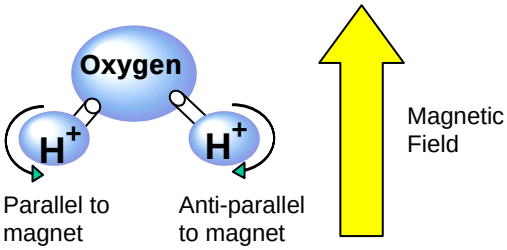
Half to 65% of your body is made up of water – that's about 45 quarts! Water is made up of two hydrogen ions and one oxygen molecule.



The two hydrogen ions that are attached to water have a "spin." This spin means that that the hydrogen ion will go around one way or the other.

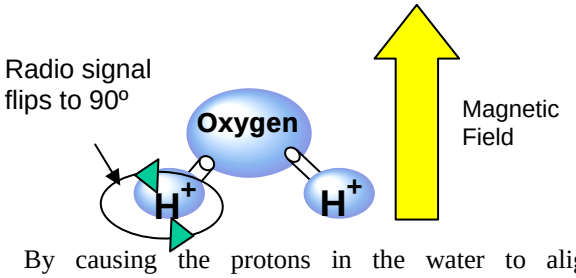


When a patient is placed into the magnetic field generated by the magnet in the MRI, the hydrogen ions found in the body's water will align (spin) parallel or anti-parallel to the magnetic field.



The next part of the MRI is to tune the radio frequency to the body part that is to be imaged (kind of like tuning your radio to the station that you want). Tuning the radio frequency will cause the hydrogen ions in the water to flip 90 degrees when the radio frequency pulse is applied.

Look at the following diagram – the magnet field is stationary, but the radio signal causes the hydrogen ions to start to align perpendicular to the magnet.



By causing the protons in the water to align perpendicular to the MRI magnet, a signal can be measured. This signal is sampled at a "time or echo". The TE is obtained by listening for the signal with a receiver coil and then sampling the tissue. The "Time of Repetition" or "TR" is how long before the next radio frequency is transmitted.

So, what does this mean? Well, by manipulating both the TE and TR, the MRI can see how long it takes the structures imaged to relax, or realign with the magnet. This will produce two types of images:

- T1 weighting: relaxation time that looks at anatomy
- T2 weighting: recovery time that looks for pathology

Different tissues have different T1 relaxation and T2 recovery times. By knowing this information, the scanning can be manipulated to look to see if a structure is fat, muscle, bone, cerebral spinal fluid, or ligament, etc....

Here is an example… Fat will be bright on a T1 image and dark on a T2 image. Water will be dark on a T1 image and bright on a T2 image. Knowing this, the MRI can see if a tumor is cystic (mostly water) or fatty.

Here is another example… Flowing blood doesn't show up on an MRI because blood flows out of the area to be imaged, so it can't give a signal back. Now, if the vessel has a clot in it, the clot will not move out of the area and will be able to give a signal back. MR angiography can then be done to help see that clot.

What equipment is used in MRI?

The MRI uses a magnet, radio frequencies, gradients, transmitter and receiver coils, and the computer to translate information into images. Let's take a closer look at all of this equipment.

Magnet

There are three types of magnets: permanent, resistive, and super-conducting. A *permanent* magnet is like the kind you put on your refrigerator at home – it always has a magnetic field. A *resistive* magnet uses some type of electricity to get it going – you can turn one on and off each day.

A *super-conducting* magnet uses liquid helium, known as cryogens, and electricity to get it going, and then once it has the magnetic field, you can take away the electricity. As long as you keep replacing the liquid cryogens, it will keep its magnetic field. You can't turn this magnet off easily.

MRI uses either resistive or super-conducting magnets. Resistive magnets are typically used in open-sided MRI systems. They usually do not have a very high field strength.

Most MRI systems use a super-conducting magnet because they allow higher field strength. The higher the field strength (measured in Tesla), the better the signal you can get, reducing the time to get images.

There are also different types of magnet bores. The bore is the length and width of the magnet itself. It is the "tunnel" the patient is put into. There is a long bore, a short bore, and an open bore. Older systems use the long bore design, although newer systems are coming with a short bore design. The short bore design is helpful for people with claustrophobia or for newer types of exams, such as MRI biopsy and interventional MRI.

Radio Frequencies

Radio frequencies are used in MRI to flip the hydrogen protons. The strength of the frequencies needed to achieve this is based on the Larmor equation, which is the strength of the magnet and the hydrogen proton processional frequency. The radio frequency may be set close to FM radio station frequencies, so the magnet room must be radio frequency shielded to block out external radio signals and other radio frequencies.

Gradients

Gradients are inside the magnet bore and are used to localize the area that we want information on. There are three physical gradients, based on the body planes, that may be used: Sagittal, Coronal, and Axial. A technologist can manipulate the use of these gradients to do oblique images, which is a combination or two or more planes.

As newer equipment comes out with faster gradients, there is increased concern for patient safety. These faster gradients may cause an increase in nerve stimulation and/or burns to the patient.

Transmitter and Receiver Coils

The transmitter coils transmit the radio frequency signal into the body. The receiver coil listens to the signal and sends it back to the computer to be manipulated into images. These coils can be part of the bore of the magnet, or the coil can be specifically designed for the particular image of the body. For example, a head coil is used to transmit and receive information for just the head that is inside the coil. The MRI works best with a localized coil to image a small part of the body – the better the coil fits the body part, the better the image. Here's another example: the technologist may use an extremity coil to image an infant's head.

You will learn about the indications and contra-indications for an MRI scan, patient preparation, and magnet safety issues in this section.

What can MRI look for in the body?

Most MRI departments characterize studies by either "neuro" or "body" examinations. Let's look at the neuro work first… Neuro work can be broken down into brain and spine imaging.

Brain	Spine
Ischemic changes	Compression fractures
Tumors	Cord contusion
Infections	Disc disease
Vascular malformations	Infections
Vascular disease	Abscesses
Multiple tumors	Demyelinating disease
Skull base tumors/infections	Congenital anomalies
TMJ disease	Nerve impingement
Parotid gland tumors	Cord impingement
	Metastases

When moving into body imaging, we break down into two categories: extremities and torso imaging.

For extremities, MRI can look for:

- Arterial and/or venous flow
- Bone tumor
- Cartilage tear
- Fractures
- Infection
- Inflammation
- Labrum tear
- Ligament tear/rupture
- Mass
- Meniscus tear
- Rotator cuff tear
- Tendon tear or rupture
- Tumor

Finally, the torso images can yield information about:

- Stenosis in the kidneys, renal arteries, common bile duct or pancreatic duct
- Tumors or masses in the liver
- The structure and presence of tumors or masses in the female pelvis
- Fractures or avascular necrosis in the hips
- Tumors or masses in the adrenal gland
- The function of the ureters through urography
- Tumors or implant leaks in the breasts
- The heart through cardiac imaging
- The aorta

The MRI procedure

General guidelines

The patient will generally be lying on the MRI table for an average of 30-45 minutes per body part examined. If doing the entire spine, that would mean 1.5 – 2.25 hours. The patient must be able to lie flat and follow instructions.

If the patient does not speak English, an interpreter must accompany the patient for the procedure. The technologist must be able to find out through the interpreter if the patient is having any difficulties during the exam.

How do I prepare my patient for MRI?

Most patients can eat and drink whatever they would like before the test. However, if they are having certain abdominal imaging, they may be requested to have nothing by mouth 4-6 hours prior to the test.

Disconnect all monitoring equipment, including patches and probes. Disconnect all non-essential IV pumps and drug-infusion pumps. You will need to plan ahead if your patient is on a CADD pump for pain medications. Alternative medications may need to be given during the test and transport time. Essential IV pumps may be kept running if high-pressure extension tubing is placed to keep the pump outside of the magnet room. Check with your institution to see how much extension tubing is needed or if they have MRI-compatible IV pumps.

Transfer the patient to an MRI-compatible wheelchair or cart. Some MRI manufacturers have tables that can be undocked from the MRI machine and brought out of the magnet room to transfer a patient onto the MRI table. Check with your facility to see how they would like to have patients transferred to their department.

Check the patient's chart to see that the screening questionnaire is filled out completely before sending the patient, and send the chart with the patient for the test. Check with the patient to see if he/she is claustrophobic (afraid of small spaces). If they answer "yes," notify the MRI department for guidelines on how to handle the situations. Some facilities have either an open bore or a short bore magnet that they can scan the patient on. Other options include either changing to a different procedure altogether or using sedation for the procedure.

Is your patient pregnant? If the patient is unsure, do a pregnancy test. If the patient is pregnant, consult with a Radiologist to see if the MRI is still indicated or if a different procedure should be performed.

How about orthopedic hardware?

Most orthopedic hardware is safe. Most total knees, hips, rods, screws, and plates are all right; however, most bone and tissue stimulators are not.

What are the contraindications for the MRI procedure?

Pacemakers, some aneurysm clips, TENS units, shrapnel (depending on the location), metal in the eyes from welding or sheet metal work, cochlear implants, and some middle-ear prosthetics are not safe in an MRI environment. All implanted devices must be screened before the patient may undergo an MRI exam.

When should caution be used?

Pregnancy, sickle cell anemia, and breast feeding are all cautions for most MRI contrast agents.

What if the patient needs sedation?

Patients, either adult or pediatric, who are unable to lie flat or hold still and follow directions must be sedated for an MRI exam. Adult sedation may be required for patients who are claustrophobic, developmentally delayed, confused, or unable to cooperate for the procedure. In addition, analgesia may be required for pain control. These issues must be addressed prior to the patients' arrival in the MRI department.

For all sedation, the patient should be NPO for four hours prior to the administration of the medication or per hospital policy.

If oral sedation is determined necessary for the scan, it should be ordered by the physician ordering the scan along with patient instructions on when to take the medication. All outpatients must have a responsible adult to drive them home.

If IV sedation is chosen, it is best practice to have these medications given in the MRI department. Many institutions have nursing staff in their Radiology departments to sedate and monitor patients during scans. The MRI department has MRI-compatible monitoring equipment in the scanning rooms so patients can maintain the same level of monitoring throughout their care in Radiology.

The examination time is the same for pediatric patients as it is for adults – 30-45 minutes per body part. Children should be evaluated for their ability to hold still during both IV insertion and the MRI procedure. Children over the age of 5 may be able to practice holding still prior to the appointment to avoid sedation. Most children under the age of 5 require sedation.

MRI departments have differing protocols for sedating children for Radiology studies. It is becoming common practice to have Pediatric Intensivists or Anesthesia assume the responsibility for managing pediatric sedations. Check the sedation policies at your organization for specifics.

A parent or guardian may stay in the room with the child during the procedure for reassurance in some facilities. That parent or guardian must go through the same screening process as the child before being allowed to entire the MRI room. Remember, a good MRI study requires that the child holds still the entire time of the procedure.

Does MRI ever use contrast?

Some MRI studies require the use of a contrast agent. MRI contrast agents are different than x-ray contrast agents. X-ray contrast generally uses iodine, whereas MRI uses a substance that can be seen using a magnet and radio frequencies.

There are two basic types of contrast agents for MRI: agents that "highlight" during the procedure and "negative" agents. The most common contrast, one that highlights, is a gadolinium-based agent. This is generally given through an IV, but may be injected directly into the joint space for an MR arthrogram. A negative agent, GastroMARK®, is used in abdominal imaging to differentiate the bowel from the surrounding organs and tissues. This agent is given orally and requires that the patient be NPO four hours prior to the procedure. GastroMARK® is not commonly used at all institutions.

Some disease processes that may require the use of contrast include tumors, masses, infections, metastatic disease, biliary obstruction, demyelinating disease, prior surgery in the area to be scanned, and contrast-enhanced MR angiography.

How is the magnet used safely?

We need to be very careful of objects that may come too close to the magnetic field. Ferromagnetic objects (objects that become attracted to the magnet) can become projectiles as they get closer to the magnetic field.

A projectile can cause damage to the magnet and anything in its way. The projectile, depending on its mass weight, will try to go through objects in its way to get the center of the magnet.

A case in point – oxygen tanks. If a non-MRI-compatible oxygen tank is brought into the magnet room, it will be pulled toward the magnet. The closer the tank gets, the stronger the pull will be. The magnetic field can pull this tank out from under the patient cart and pull it into the magnet. If a person is in the way, it will hit and possibly crush the person. There have been several cases of severe injury and death, including that of a young child in New York, related to this.

Here are some examples of objects that can become projectiles:

- Oxygen tanks
- Crash carts
- Housekeeping floor buffers
- IV poles
- Scissors
- Patient charts
- Pens
- Walkers
- Canes
- Crutches
- Paperclips
- Safety pins
- Hair pins
- Stethoscopes
- ID badges with metal clips
- Non-MRI wheelchairs, carts, and monitors

Other external objects that must be removed before entering the magnet room include:

- Jewelry
- Keys
- Coins
- Credit cards or any card with a magnetic strip
- Pagers
- Cell phones
- Cigarette lighters
- Knives
- Fingernail clippers
- Scalpels
- Guns
- Barrettes
- Head bands
- Steel toed shoes

What are the patient safety concerns?

Patients may have metal inside or externally attached to their bodies. Any metal, in the setting of MRI, has the potential to cause artifact, heating, or metal dislodgement.

Artifact

Artifact is caused by metal in the magnetic field. Artifact usually causes a "black hole" on the MR image. Orthopedic hardware would cause this type of artifact. If we are trying to image the knee and the patient has had a fracture with screws in the knee, it would be very difficult to image in that area. Images may still be obtained above or below the metal.

MRI compatibility of implants

To find out if implants are MRI compatible, you need to know the name and manufacturer of the implant and how long the implant has been in the person's body. Once that information has been obtained, the implanted device needs to be cleared by the MRI staff. The referring physician should place a call to the MRI department with the information and, depending on the implant, the technologist may be able to clear the patient using a reference book in the department telling which objects are safe at what magnetic field strength. If the technologist is unsure, the radiologist will be consulted for clarification.

Heating and Burns

MRI can cause heating and burns to the patient. Any coil of wire placed inside of a magnetic field with the induction of a radio frequency can produce a current (Faraday's law of induction). The best example of this is an ECG lead. If a patient placed inside of a magnet has ECG wires attached to pads, a current can be produced. The current will ground to the patient, causing burns. All patients should be sent to MRI with their monitoring equipment intact to provide continuous monitoring as they are transported through the hospital. MRI staff will change the patient to MRI-compatible monitoring systems and arrange for nursing to monitor sedate as required.

What can cause burns?

- "BB's" from a gun
- Body piercing
- Bullets
- ECG patches/wires
- Faulty or improper use of MRI coils
- Hairpins/safety pins
- Holter monitors
- Indwelling monitors
- Pacemakers
- Pulse oximetry probes
- Shrapnel
- Some tattoo ink
- Swan-Ganz catheters
- TENS units
- Urinary catheters with temperature probes
- Non-MRI wires

Dislodgement

Metal devices and pieces can be dislodged in the patient during the MRI scan because of the magnet. Examples include:

- Aneurysm clips
- Cochlear implants
- Vascular clips
- Vascular coils
- Vascular stents

All patients and visitors to the MRI department must be screened before entering the magnet room. The screening form must be completed for all persons.

All patients should be screened for internal and external metal before coming to the MRI department. An area that is frequently overlooked is metal in the eyes. Welders, sheet metal workers, and patients that grind metal need to be screened. You need to make sure that the patient does not have any metal shavings in the eye. If the person is placed into the magnetic field and there is metal in the eyes, the metal could twist and/or turn.

MRI is a valuable imaging tool, but it can be harmful, or even deadly, to all who are around it. Please screen yourself and your patients before going to the MRI department.

Shutting down the MRI magnet

In the event of a magnet safety breach, the magnetic field may need to be "ramped down"– in essence, turned off.

If it is a life-and-death emergency, the staff can "quench" a super-conducting magnet. To quench a magnet is to quickly release its liquid cryogens into the air to decrease the magnetic field. This takes time – possibly 30 minutes or more.

Quenching a magnet has two negative consequences:

1. There is the risk that the magnet will be permanently ruined. Replacement will cost about $500,000.00.

2. The cryogens may be let loose inside the magnet room, which can decrease the amount of oxygen left in the room. The magnet room door must be left open so that workers will not be trapped in an oxygen-deprived environment.

If it is not a life-or-death situation (i.e., an object is lodged to the magnet but there is no one in the room) the MRI staff can call their service engineer to come in and ramp the magnetic field down. "Ramping the magnet down" is a controlled reduction in electrical power which reduces the magnetic field. To do a ramp down takes hours, but reduces the risk to the magnet and staff. Neither situation is good and should be avoided by the screening process.

When the magnet is quenched or ramped down, there is a loss of revenue as well as major inconvenience, as patients requiring an MRI would have to be sent to another facility. Estimates for a quench are in the $60,000 to $80,000 range, which includes service and cryogens. This cost does not reflect the cost of a new magnet, service to damaged equipment, or any injury or death incurred to patients or staff.

Summary

MRI scanning has become more and more a staple of today's health care diagnostics. This complicated piece of machinery can help physicians to diagnose many different diseases, pathologies, and conditions to optimize interventions.

The MRI scan is not without risk, however, and knowing how to prepare your patient, yourself, and others to be safe around the magnet and during the procedure is paramount in getting the best outcome for your patient.

Directions for Submitting Your Post Test for Contact Hours

To obtain a certificate of completion for this home study program, please complete the post-test and evaluation on the next few pages. The date on your certificate of completion will be the date that your home study is received. **Any materials received with a postmark after the expiration will be discarded.**

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If you are an employee of HealthEast, HCMC, or MVAMC, you may send the post-test and evaluation to TCHP for processing. Your post-test will be returned to you through your hospital. It cannot be mailed to your home.

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If you are not an employee of one of the TCHP hospitals, please send the post-test and evaluation to TCHP with a check for $6.00. Please make check payable to **TCHP Education Consortium** and mail to:

TCHP Education Consortium
Capitol Office Building
525 Park Street, Suite 120
St. Paul, MN 55103

Your post-test will be returned to you with the certificate of completion.

MRI Scanning Post-test

Please print all information clearly and sign the verification statement:

Name_____
(please print legal name above)

Birth date (required)

Format: 01/03/1999

M	**M**	**D**	**D**	**Y**	**Y**	**Y**	**Y**

For HealthEast, HCMC, or MVAMC, employees only:

Hospital _____ Unit_____

Personal verification of successful completion of this educational activity (required):

I verify that I have read this home study and have completed the post-test and evaluation.

_____
Signature

1) Clinical MRI uses what abundant substance in the body to take images?
   a) Phosphorus
   b) Fat
   c) Water
   d) Blood

2) The strength of the magnet is measured using what unit?
   a) Gauss
   b) Tesla
   c) Homogeneous
   d) Hertz

3) In MRI, you must be concerned about which two safety issues?
   a) Magnet safety and fire safety
   b) Patient safety and employee safety
   c) Employee safety and fire safety
   d) Magnet safety and patient safety

4) Which object below is a contraindication to MRI?
   a) Implanted wires
   b) Aneurysm clip
   c) Pacemaker
   d) All of the above

5) All implanted devices must be cleared by the MRI staff before an MRI procedure can be performed.
   a) True
   b) False

6) MRI uses what devices to image the body:
   a) Magnet
   b) Radio frequencies
   c) Gradient coils
   d) All of the above

7) Mr. Jones can have an MRI of his left ankle. He had a pacemaker removed but still has the pacer wires.
   a) True
   b) False

8) My patient is on a cardiac monitor. Before sending him to MRI, I can unplug the wires from the monitor but keep the wires attached to the patches on him.
   a) True
   b) False

9) A patient needs to be able to do what in order to get a good MRI study?
   a) Lie flat
   b) Hold still
   c) Follow directions
   d) All of the above

10) I do not worry about getting the nausea and vomiting of my patient under control before the MRI.
   a) True
   b) False

Expiration date: The last day that post tests will be accepted for this edition is **December 31, 2018**—your envelope must be postmarked on or before that day.

Evaluation: MRI Scanning

Please complete the evaluation form below by placing an "X" in the box that best fits your evaluation of this educational activity. Completion of this form is required to successfully complete the activity and be awarded contact hours.

At the end of this home study program, I am able to:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Describe how an MRI obtains tissue images.					
2. Identify safe and unsafe items the magnet room.					
3. Identify the patient safety concerns related to MRI scanning.					
4. Describe the preparation of the patient and procedure for an MRI scan.					
5. The teaching / learning resources were effective. *If not, please comment:*					

The following were disclosed in writing prior to, or at the start of, this educational activity (please refer to the first 2 pages of the booklet).		
	Yes	**No**
6. Notice of requirements for successful completion, including purpose and objectives		
7. Conflict of interest		
8. Disclosure of relevant financial relationships and mechanism to identify and resolve conflicts of interest		
9. Sponsorship or commercial support		
10. Non-endorsement of products		
11. Off-label use		
12. Expiration Date for Awarding Contact Hours		
13. Did you, as a participant, notice any bias in this educational activity that was not previously disclosed? *If yes, please describe the nature of the bias:*		

14. How long did it take you to read this home study and complete the post test and evaluation:

    _____hours and _____minutes.

15. Did you feel that the number of contact hours offered for this educational activity was appropriate for the amount of time you spent on it?

    ____Yes

    ____No, more contact hours should have been offered

    ____No, fewer contact hours should have been offered.

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