

**INTERNATIONAL
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Interview on Emergency Radiology
United States/Dr. Joseph S. Yu**

In the United States, technical advances in CT, such as dual-energy CT, remain at the forefront of radiological innovations in emergency departments, according to Dr. Joseph S. Yu

European Society of Radiology: *Please summarise the innovations and trends in state-of-the-art emergency and trauma radiology? In other words, what's new in emergency radiology?*

Joseph S. Yu: Over the years, there have been many innovations that have moved the needle in favour of the patient in regard to emergency radiology. The technological advances in CT have remained at the forefront, largely because imaging is so fast; the equipment had become ubiquitous; and the limits in resolution have been pushed further so that we are able to look for and find very small pathology, be it in the bone or in the soft tissue. There are few instances where CT has not contributed to the care of patients in the emergency department, particularly in cases of severe trauma, such as victims of motor-vehicle collisions.

These days, the most exciting advance in CT is the advent of dual-energy CT, a relatively new technology that uses x-rays of two different strengths to create an image. A standard CT scanner uses a single, polychromatic x-ray beam. This beam penetrates tissues, and images are produced based on the amount of attenuation of these x-rays (i.e. how much of the x-ray is not transmitted through the tissue) and how closely the energy of the x-ray exceeds the binding energy of the inner electron shell. Tissue attenuation can be manipulated by changing the strength of the x-ray beam. A dual-energy CT uses both the standard x-rays (at 140 kVp) and a second, less powerful, x-ray (at 80 KVp), thus expanding the versatility of the CT scanner. The significant advantage of this type of scanner is the ability to exploit the effects of certain chemicals or substances in the body. For instance, typically we use iodinated intravenous contrast material to enhance the vascularity of tissues. Dual-energy CT can select for iodine and create exquisite pictures of the blood vessels, as well as identify locations of contrast extravasation arising from injured organs that are leaking blood. It can improve the quality of scans markedly in patients who have metal in their bodies, such as artificial joint replacements, by selecting the energy that reduces artefacts; or it can differentiate between the types of kidney stones, thus influencing the proper treatment. Material separation allows visualisation of noncalcified gallstones, and helps distinguish it from cancer so that therapeutic decisions are more precise. An important application in trauma patients is detection of bone marrow oedema to assess subtle fractures that previously could only be done with MR imaging. MR imaging in acute trauma patient is not always possible. The potential application of this technology is bright for future tumour imaging.

ESR: *What do you think are the most significant changes you have seen in emergency radiology since you began your training?*

JSY: There have been numerous advances and innovations introduced during the past two decades that have dramatically influenced the manner in which radiology contributes to the care of patients in the emergency department.

First, technological advances remain the driving force that has allowed imaging to keep up with demand in the emergency department. A huge advancement is the advent of multidetector computed tomography over a single-source CT. It created an unprecedented escalation in CT use, with an exponential growth from 1990 to 2005. Much of that growth occurred in emergency departments across the country. During this period, there was roughly a three-fold increase in the number of CT studies performed. Multidetector CTs made it possible to scan much faster, which allowed the ability to scan organs, such as the heart with a single breath-hold, and eliminated respiratory artefacts that previously had the potential to degrade image quality. Additionally, faster scanning introduced imaging in different vascular phases, and the development of CT angiography has largely replaced catheter-based diagnosis. Other technological advances include image reconstruction into three-dimensional anatomic depiction, which improved the understanding of bone and soft-tissue trauma; and the introduction of newer applications, such as CT colonography. However, the explosion of new technology also added to the complexity, as well as to the number, of images that accompanied each study.

Secondly, the most important innovation in the emergency department is the evolution of around-the-clock, in-house staffing using full-fledged emergency radiologists (i.e. board-certified or board-eligible radiologists who have completed a diagnostic radiology residency). This provides high-quality, final interpretations of imaging procedures performed on all emergency department patients and on inpatients who require emergent imaging. Historically, after-hours imaging procedures performed in the emergency departments of academic institutions were given a preliminary reading by a radiology resident, who then reviewed the studies with a board-certified faculty member the following morning. Any discrepancies in interpretation were reported to the emergency department staff, and, if necessary, the patient was called back for additional evaluation or change in treatment. This often meant the care of the patient was performed by an entirely different team of doctors. In many smaller emergency departments, the initial, primary reads were often made by non-radiologists. There were two major events that contributed to the creation of a 24-hour, in-house model. The first was a ruling by the Medicare, the federally funded payer in the United States, that payment for services rendered in the emergency department would go to only one provider, and that billing for the study would be reimbursed only if interpretation of studies was simultaneous with patient treatment. The second event was the rapidly accelerating use of CT, which required a level of expertise that often exceeded a non-radiologist's scope of practice.

Thirdly, the picture archiving and communication system (PACS) has revolutionised radiology. This advancement has changed the way images are accessed and stored in institutions, and has dramatically improved clinicians' access to these images from anywhere in the world. With digital images, anyone with an electronic device or computer can view a patient's study. This has promoted a transparent method of patient care; created efficiencies that were not present before; and elevated the quality, timeliness, and delivery of treatment.

ESR: *Please describe the role of the radiologist in a typical emergency department in the United States?*

JSY: Radiologists perform one of the most critical tasks in the emergency departments of many institutions. They serve as the diagnostic hub where all patients who require imaging studies flow through. When multiple trauma patients do present, they consume the undivided attention and access to equipment that radiology offers; all other patients wait as the polytrauma victim receives an array of services in a brief, but intense, time interval. However, the vast majority of emergency department admissions are patients with acute, self-limiting processes or those with complications of one or more systemic conditions that require hospitalisation. These patients also need prompt radiologic consultation and imaging in order to justify hospital admission and to begin therapy. As such, a close relationship between radiology and emergency medicine makes the enterprise more efficient.

The actions of the radiologist influence the outcome of many patients, but especially polytraumatised patients who have been involved in motor-vehicle collisions or have suffered

penetrating injuries from gun violence or industrial accidents. In our department, we employ six subspecialty emergency radiologists, only one of which works during daytime hours (8am to 5pm). Therefore, interpretation of all emergency department studies is a shared responsibility with subspecialty radiologists in other sections. Because the interpretation of daytime examinations performed in the emergency department take precedence over outpatient studies and non-emergent examinations performed on inpatients, the workflow design dictates that all imaging studies from the emergency department are colour-coded and prioritised in the PACS. These studies appear as 'first study to read' by an algorithm that moves these examinations to the top of every worklist, independent of subspecialty, so that emergency department patients receive expeditious attention throughout the department.

ESR: *What does a typical day in the emergency department look like for a radiologist?*

JSU: I work in a large, academic institution with approximately 1,600 hospital beds. We are considered a tertiary care centre and we have a Level 1 trauma designation by the American College of Surgeons, which means that we can accommodate all types of emergencies. It requires 24-hour, in-house coverage by general surgeons and prompt care available by orthopaedic surgery, neurosurgery, anaesthesiology, emergency medicine, radiology, internal medicine, plastic surgery, oral surgery and critical care.

The emergency department has more than a 100-bed capacity. The radiology department provides in-house, around-the-clock coverage of our emergency department throughout the year, including weekends and holidays. Our emergency radiologists have their reading rooms physically located within the emergency department and adjacent to four trauma bays, each capable of handling two trauma patients at a time. We work in three shifts that overlap by 2 to 4 hours during peak times. Two shifts are 8 hours long and a third is 10 hours long. In a typical 24 hour day, we will interpret 50 to 80 CT examinations, 20 to 30 MR examinations, and about 12 to 20 ultrasound studies in addition to about 150 to 200 radiographs between three radiologists. On average, three to six Level 1 trauma patients are flown in to us via a two, dedicated helicopters, distributing trauma patients between two Level 1 hospitals in our city.

The patients we evaluate in our department present with a wide variety of conditions, including musculoskeletal injuries resulting in fractures dislocations, and muscle and ligament tears; blunt trauma that produces a spectrum of pathology from liver lacerations to pneumothoraces; penetrating injuries arising from knife or gunshot wounds; in addition to severe multiorgan injuries often seen in polytrauma patients. We assess ischaemic or thrombotic events that result in strokes, ischaemic bowel or necrotic tissue. As a stroke centre, each patient has a timer, initiated from the onset of symptoms, so that treatment is rapid and offers the best chance of recovery. Infections are common. Conditions such as necrotising fasciitis are life-threatening and require expeditious access to imaging so that the extent of disease may be documented, either for preoperative assessment or as a baseline for progression. As a heart hospital, a large number of patients who present with symptoms that suggest an evolving heart attack have a unique pathway to the angiographic suites for diagnosis and administration of thrombolytic therapy.

ESR: *Teamwork is crucial in an emergency department. How is this accomplished in your department, and who plays the most crucial roles on your team?*

JSY: Teamwork is important in any part of medicine, but it is particularly critical for successful evaluation of an acutely ill or traumatised patient. Nowhere is this more evident than when a Level 1 trauma patient arrives in the emergency department. A patient who has suffered severe multiorgan trauma from a motor-vehicle accident, for instance, requires cooperation between the attending emergency physician, who is part of the teaching faculty, and any number of residents from different departments. Once the patient has been triaged and the appropriate imaging studies have been ordered by the emergency physician, the general surgeon or the orthopaedic surgeon will then take the lead for the subsequent care of the patient, depending on what is discovered through

imaging. In these trauma patients, a standard battery of imaging includes radiographs of the chest and pelvis, and CT examinations of the cervical spine, abdomen/pelvis, and often the head. Additional radiographs and CTs are requested based on physical examination. It is not unusual for a severely injured patient to undergo additional CT of the chest, and the rest of the spine, and to have additional radiographs performed of the extremities. Patients who suffer penetrating injuries from knife wounds or gun-shot wounds often end up in the care of cardiac surgeons or neurosurgeons, depending on the magnitude of their injuries.

The commonality in all of these types of trauma is the contribution of the emergency radiologist, who provides instantaneous, final interpretation of all studies generated during the care of the traumatised patient. In our department, the goal is to have less than one hour of turnaround time for all studies in the emergency room, but we aim for 30 minutes for the majority of patients. The emergency radiologist also works closely with the radiology technology staff to ensure that images are ready to be interpreted as soon as they are completed, so that a final report may be generated. If patients bring CDs of images from another institution, the radiologist imports these images to the PACS and provides interpretive support for these outside studies. Generally, radiologists report their findings directly to the emergency physician or the lead trauma surgeon who has assumed primary care of the patient.

ESR: *Are you satisfied with the workflow and your role in your department? How would you like to see it improved?*

JSY: Yes, we are satisfied with the workflow and the contribution of the emergency radiologist to the department. The workflow is a culmination of the efforts of many individuals in multiple departments. The institution is supported by a large IT department that oversees the network, servers, computers, data flow and storage of information. We collaborate with members of our own informatics team, which facilitates the distribution of studies, maintenance of departmental servers, and a smooth functioning workflow, so that each section is working at maximum efficiency. We have 10 years of patient-file storage in our department, but retrieval of prior studies requires methodical directives and implementation of careful selection criteria to enable a rapid retrieval without impairing the speed of image delivery to the PACS, since a large storage archive can slow the speed of the PACS. This affects how quickly one can scroll through a study with multiple images like CT or MRI; move from one patient to another; and manipulate images, such as three-dimensional pictures. Providing an environment that is optimal is expensive and requires the availability of recurring financial resources and investments. Avoiding change leads to stagnation quickly. Having leadership in an institution that always considers factors that increase the efficiency of patient care delivery in a digital world is important and one of the major things that ultimately adds to our job satisfaction.

ESR: *Which modalities are used for different emergencies? Could you please give an overview, sorted by modalities? Which modalities are most essential to emergency room practice?*

JSY: In most instances, radiography is the standard imaging modality to get an overview of the chest, abdomen, pelvis, or appendicular skeleton. It is an adequate technique to evaluate the bones for fractures in trauma, lungs for pneumonia, or free air in the abdomen.

CT is the workhorse in the emergency department for neuroradiological, abdominal, and cardiovascular conditions. Non-contrast CT is used to assess most cases of headaches, which may be an indication of a haemorrhage, stroke, aneurysm or cancer. CT of the spine is used in patients who have back pain after significant trauma or in whom the radiographs are positive for fracture. This allows full evaluation of all of the areas that are involved. In an acute polytrauma scenario, a patient frequently undergoes a head CT, chest CT, abdomen and pelvis CT, and spine CT, when necessary. Abdomen pain also is amenable to evaluation with CT and in these situations, both enteric and intravenous contrast generally are administered. CT also is an effective modality to search for gas or inappropriately located air. Since many infectious processes result in the collection of gas, CT is

particularly useful. CT detects acute blood products, so it is often used to evaluate whether patients who present with decreased haemoglobin are actively bleeding or have accumulated a haematoma. MRI is most useful for assessment of soft tissues, owing to its superior contrast resolution. Specific tissue types are depicted differently in the various imaging sequences used on MR. It is relatively easy to differentiate between scarring, acute swelling, fluid containing structures, solid masses, vascular structures, and tissues that contain blood products. It is useful to search for radiographically occult fractures of the wrist or hip; or for evaluation of the disc if a disc protrusion is suspected as the cause for acute neurologic symptoms. In the spinal column, it is the modality of choice when spinal cord impingement, nerve disease, or disc infection is suspected. It is the primary modality to evaluate for acute ligament tears, such as the anterior cruciate ligament in the knee; tendon pathology such as rotator cuff tears in the shoulder; and soft-tissue injury, such as a muscle contusion. It is the preferred modality in evaluating for soft tissue or bony infections, both in acute and chronic situations, since contrast resolution of MRI is unparalleled. It also is frequently used in evaluating patients with cancer who may present with an acute complication such as a pathologic fracture, nerve impingement, or acute haemorrhage.

Ultrasound also has a role in the emergency department. It is an effective method to search for free fluid in the abdomen; to assess soft-tissue masses as either solid or cavitary; and to evaluate the vascularity of certain conditions, such as arteriovenous malformations that can present with pain or a mass.

ESR: *Is teleradiology an issue in emergency radiology? If yes, how so, and how often is it used?*

JSY: Not all emergency departments require the same quality of coverage. Level 1 trauma centres differ greatly from a small, rural hospital in terms of the types of patients who present to the emergency department. Because the needs are different, and owing to a relative shortage of radiologists willing to work after hours or at night, teleradiology has flourished and is used in many institutions to cover emergency radiology patients. Only about 27% of academic institutions provide 24-hour attending coverage of the emergency department by board-certified or board-eligible radiologists. More than 75% of academic centres continue to provide preliminary interpretations of night-time studies performed by residents with different experiences. It requires tremendous departmental and institutional resources to provide 24-hour, faculty coverage. There also are variations in payment and time-off compensation that are expected by those who provide this service. It is an issue of scale and affordability. As Medicare continues to exert pressure for contemporaneous interpretation of imaging procedures in emergency department patients, teleradiology groups are stepping in to provide these final readings for many institutions.

ESR: *Are emergency radiologists active anywhere other than emergency departments? Do they have other nonemergency roles, or other emergency roles in other departments?*

JSY: In many departments, an emergency radiologist performs a dual role by interpreting imaging studies in their respective subspecialty and to providing subspecialty coverage of the emergency department. This is particularly true in neuroradiology, where final interpretations often are required to begin treatment. For instance, this is especially applicable in patients who present with an evolving stroke, where time is of the essence and initiation of appropriate therapy is critical for a favourable outcome. In other situations, the complexity of the vascular anatomy in the brain necessitates a subspecialist to read MR or CT angiographic studies to facilitate therapeutic intervention, such as embolisation of a bleeding vascular malformation or coiling an aneurysm. Alternatively, emergency radiologists, who frequently work in shifts, may be called upon by the chief or chair of the radiology department to contribute their expertise during routine work hours to assist a section in the department that may be short-staffed because of meetings, vacations or attrition. Since it is in the scope of the emergency radiologists' practice to interpret a broad spectrum of studies and modalities, and recognise a wide latitude of pathologic conditions, they are

nimble and may easily be deployed into various areas of a department in the event of a staffing need.

ESR: *Do you have direct contact with patients, and if yes, what does it entail?*

JSY: My contact with patients is limited to three types of interactions. First, I have an opportunity to speak to patients whenever there is a need for an interventional procedure, such as an emergent joint aspiration to exclude or confirm an infected joint. Generally, a limited physical examination is required by our institution prior to the procedure, and this allows the radiologist to search out any prior studies that may accompany the patient, and also gives the patient time to ask questions. A second opportunity arises when a patient has questions prior to an imaging procedure. Because we are located within the emergency department, patients have access to radiologists whenever they have a specific question related to their imaging study, or if they have a particular question or concern. We encourage the technologists to call us when a patient has a question. The third opportunity is when patients having a CT or MRI suddenly become symptomatic after intravenous administration of contrast media. When this occurs, radiologists respond rapidly and provide treatment if necessary.

ESR: *How are radiologists in the United States trained in emergency radiology? Is emergency radiology a recognised specialty in the United States?*

JSY: There are two common pathways for a radiologist to train in emergency radiology. In both instances, the physician must first complete a diagnostic radiology residency after medical school. Then the radiologist may seek a direct pathway by choosing a fellowship that is dedicated to emergency radiology. Currently, there are 13 of these in North America. The other pathway is more conventional; the radiologist selects a diagnostic fellowship in neuroradiology, musculoskeletal imaging, thoracic imaging, or body imaging. After completing either fellowship, the radiologist focuses on the care of the urgent and emergent patient.

In the United States, emergency radiology is not a recognised subspecialty of diagnostic radiology by the American Board of Radiology (ABR) as a specialty track for certification. However, it has been recognised by many major radiologic societies as a specific educational track, including the largest radiologic society, the Radiological Society of North America (RSNA). The American Society of Emergency Radiology (ASER) has been in existence for nearly 30 years and its flagship journal, *Emergency Radiology*, has been published since 1994. Other international societies dedicated to emergency radiology formed in Europe and Asia.

One of the impediments to emergency radiology becoming a subspecialty of radiology is the demarcation from general radiology, even though the conditions and diseases that present to the emergency department are clustered around very specific acute and subacute pathology. Additionally, knowledge requirements in general radiology include classifications that often are not appropriate to the urgent patient, and the breadth of certification questions are of greater latitude than the entities that fall in the scope of the emergency radiologist's practice. There are ongoing efforts to bring these differences to light with the ABR and to work toward a certification process that would be specific for this group of radiologists.



Dr. Joseph S. Yu is currently the vice chairman of academic affairs and education; and professor of radiology and orthopaedic surgery; and obtained his medical degree from the Ohio State University in Columbus, Ohio, United States. After completing a residency in diagnostic radiology there, he trained with Dr. Donald Resnick at the University of California in San Diego, California. Since then, he has authored more than 300 papers, chapters and abstracts, and given 170 national and international lectures, including 20 visiting professorships. He is the author of *Musculoskeletal*

Imaging: Case Review, now in its 3rd edition and on the best-selling list of musculoskeletal textbooks. He was co-editor of the 2008 American Roentgen Ray Society (ARRS) course syllabus, 'State-of-the-Art Emergency and Trauma Radiology' and in 2015, of 'Problem Solving in Emergency Radiology', endorsed by the ASER. To date, Dr. Yu and coinvestigators have received more than \$11 million in grants, including the Osteoarthritis Initiative Grants. He currently serves as president of the ASER. He has served on numerous national and international committees in many organisations, including the ABR, American College of Radiology (ACR), International Skeletal Society (ISS), ARRS, and the RSNA. Dr. Yu has received honorary fellow status in the ASER and ACR.