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Past, Present, and Future of Emergency Radiology

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In the past 2 decades, emergency radiology has emerged as an important subspecialty of medicine. Although relatively new, the growth of this subspecialty has been rapid and parallels the growth of the specialty of emergency medicine. As a subspecialty of radiology, emergency radiology is defined by the imaging and imaging management of patients who are acutely ill and injured. The primary responsibility of the emergency radiologist is not only the imaging of patients in the emergency department (ED) at all times but also off-hours emergency imaging of all patients in the medical centre.

The founding of the major professional societies of emergency medicine and emergency radiology also occurred in parallel. Aiming to improve the quality of emergency care, emergency physicians founded the American College of Emergency Physicians in 1968 with the goal "to educate and train physicians in emergency medicine." The first emergency medicine residency was created in 1970, and the specialty was recognized as the 23rd medical specialty in 1979 with the first board examination in 1980. Currently, the American College of Emergency Physicians represents more than 28,000 physicians and publishes the journal *Annals of Emergency Medicine*.

Radiologists who wished to improve the imaging care of emergency patients founded The American Society of Emergency Radiology (ASER) in 1988. The mission of ASER is to "advance the quality of diagnosis and treatment of acutely ill or injured patients by means of medical imaging and to enhance teaching and research in emergency radiology." ASER membership comprises more than 700 national and international members, and the society has hosted annual scientific and educational meetings on emergency radiology since 1990. ASER publishes the journal *Emergency Radiology*, which has chronicled numerous innovative scientific and clinical developments of the field of emergency radiology.

The academic, clinical, and professional footprint of emergency radiology has grown significantly over the years. To date, emergency radiology has achieved recognition over the years by numerous other institutional and academic entities (Table 1). Publications in the field of emergency radiology have grown significantly as seen with searches for titles and abstracts with the keyword "emergency radiology." In this review, we will highlight the past, present, and future of the specialty of emergency radiology.

Emergency Radiology: Past

Before cross-sectional imaging, emergency radiology mainly consisted of radiography and fluoroscopy. Daily practice included radiographs of the chest, abdomen, skeleton, and occasional intravenous urograms, upper gastrointestinal series, and barium examinations. Patients with acute central nervous system and vascular conditions were examined with emergency angiography. Many patients were unable to have completion of imaging examinations in the ED. Patients with diagnostic uncertainty were usually admitted to the hospital for preparation of fluoroscopic procedures or for angiographic examinations.

Growth of Imaging and ED Visits

Several factors have made a significant change in the practice of emergency radiology. These include the development of cross-sectional imaging, an increase in volume of ED patient visits, increased emergency physician imaging expectations, and cost-containment initiatives from health care reform. The introduction of emergency computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound have revolutionized the practice of emergency radiology.

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Table 1
Selected highlights: emergency radiology is recognized by multiple institutional and academic entities

RSNA refresher course track
ARRS instructional course track
RSNA/ARRS scientific paper sessions
Emergency radiology editors of radiology
Emergency radiology editors of radiographics
ABR required emergency radiology training
Fifteen emergency radiology fellowship positions at 8 medical centres

ABR = American Board of Radiology; ARRS = American Roentgen Ray Society; RSNA = Radiological Society of North America.

The increase in emergency imaging expectations has been significant. Emergency physicians have demanded the rapid availability of all imaging modalities, high-quality imaging examinations, short waiting times, immediate reporting, real-time postprocessing (3-dimensional, perfusion imaging), and 24 hours, 7 days a week service and/or coverage. Although overutilisation of advanced imaging modalities are not cost effective, advanced imaging in the ED can lead to benefits such as a decrease of unnecessary admissions and decrease in length of stay in both the ED and the hospital.

Emergency medical care has been in high demand by patients, which results in a significant increase in ED utilisation [1]. According to the 2008 Emergency Department Summary of the National Hospital Ambulatory Medical Care Survey, the number of annual ED visits totaled 123.8 million, with the volume of ED visits increasing at 2%-5% per year [2]. Between 1991 and 2006, ED visits increased from 88 million to 120 million, whereas the number of EDs decreased from 5100 to 4600 due to facility closure. At our institution, ED visits increased annually, with the busiest months in June through September.

Medical imaging initially outpaced the trends of overall ED visits and has only most recently stabilized, and is now parallel to the growth of ED visits. At our institution, our ED patient-visit volume increased 2%-3% per year, from 55,000 patients in 1996 to 110,000 patients in 2009. From 1997-2003, image utilisation growth was greater than growth in patient visits. Although there still is growth in imaging, image utilisation growth has stabilized with parallel growth with patient ED visits between 2003 and 2009. In the past year, from 2011-2012, this has increased by 6%.

Cross-Sectional Imaging Growth

Explosive growth of cross-sectional imaging, particularly CT, has characterized the most recent history of emergency radiology, having currently grown to approximately 33% of total ED imaging volume at our institution. There were 8000 CTs performed in 1996 compared with 36,000 CTs performed in 2009 (98 CTs/d). Commonly ordered CT examinations have been increasing steadily over the years and most recently stabilized. The highest volume of CT studies includes imaging of the abdomen and head experiencing the fastest growth in the past 2 decades. In thoracic imaging in the ED, since 2001, there has been a significant growth in CT used for evaluation of pulmonary embolism.

Emergency medicine practice has been improved by the advances in emergency radiology. In the past, patients in the ED were admitted to the hospital for diagnostic evaluation. Today, advanced real-time diagnostic imaging and online interpretation are performed and completed while the patient is in the ED, 24 hours a day, 7 days a week, and 365 days a year. Results often determine if an admission occurs, to which service the patient is admitted, and if there is any immediate emergency or surgical intervention. Real-time diagnostic imaging of the patient in the ED can expedite patient care and ultimately reduce costs.

Emergency Radiology: Present

The emergency radiology facility has become the hospital's acute diagnostic imaging centre. The emergency radiology division of today is unique in its physical design, equipment, staffing, information systems, and operations.

Facility Design and Equipment

Designing the emergency radiology facility today requires proper planning to optimize workflow, as summarized in Table 2. For example, radiology should be centrally located (Figure 1) for maximal accessibility to physicians and patients from multiple clinical services. The selection of imaging equipment is important to best accommodate the expected volume unique to one's ED. At our institution, we have optimized our imaging equipment to meet volume demands of acute care (Table 3).

Multidetector CT scanners in the ED enable total body trauma scans, including CT angiograms of the head, neck, and extremities. The latest technologies for dose reduction would also be beneficial and essential. Dual-source and dual-energy CT scanners would be advantageous for emergency cardiac imaging.

The convenience of an magnetic resonance (MR) scanner within or adjacent to the ED dramatically improves the level of patient care. In our institution, we also have an MRI scanner available to evaluate stroke, complex head trauma, musculoskeletal injuries, and acute conditions in pregnant patients or in children. MR safety basics must be adhered. Proper training of individuals must be performed before allowing access to the MR scanner area. Controlled access

Table 2
Designing an emergency radiology facility for today

Determine location of radiology in the emergency department
Review imaging statistics and trends to determine type and volume of examinations in emergency radiology
Prepare a comprehensive architectural program based on examination statistics and predictions
Select proper imaging equipment: radiography, computed tomography, ultrasound, magnetic resonance
Assign spaces for image interpretation, reception, patient waiting, technology staff, and on-site managers

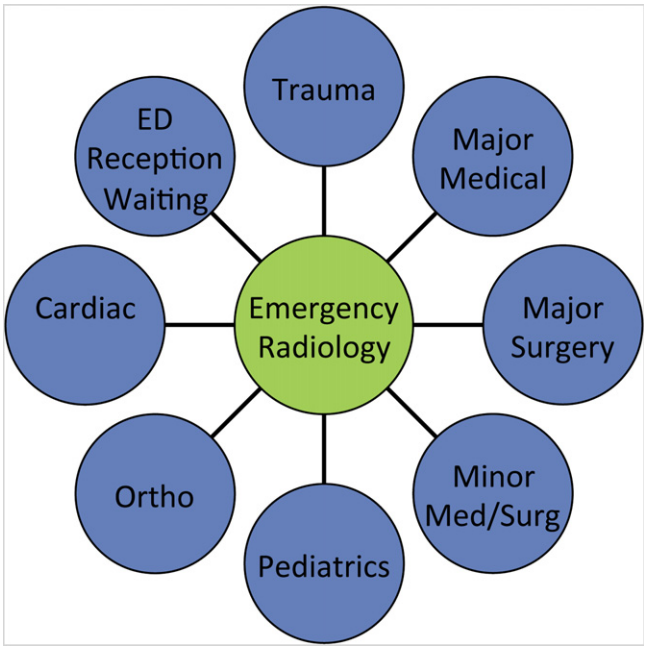

Figure 1. Location of the emergency radiology facility should be centrally located. Emergency department physicians and patients must travel to emergency radiology. ED = emergency department; Med/Surg = medical-surgical; Ortho = orthopaedics. This figure is available in colour online at http://carjonline.org/.

must be maintained to ensure safety and security. For example, access to the MRI suite and control room might be controlled with electronic key card entry (Figure 2).

Reading Room Configuration

The emergency radiology reading room should also incorporate various key components. For example, the reading room should be equipped with sufficient workstations for both interpretation by radiologists and the review of cases by referring physicians. All workstations should ideally have Picture Archiving and Communication System (PACS) and word-recognition dictation systems. The availability of 3-dimensional workstations for maximum intensity projections (MIP), volumetric, and perfusion image analysis would also be beneficial (Figure 3). Furthermore, the space should be physically large enough for physicians and teams to review imaging studies and for educational conferences. At our institution, the availability of a flat-panel display would also enhance learning and image review by teams (Figure 4).

Table 3
Sample equipment in emergency radiology facility at our institution

Three digital radiographic rooms (1 dedicated chest unit and 2 multipurpose rooms)
Two multidetector computed tomography scanners
One magnetic resonance scanner
One ultrasound room
Large consultation and/or reading room
Stretcher and/or ambulatory patient waiting spaces
Technologist computer work space
Reception and/or scheduling desk
On-site manager's office

Staffing

Physician and nonphysician staffing is also crucial to an efficient emergency imaging facility. Emergency radiologists should be available to provide interpretations of imaging around the clock, including all off-hours shifts. Managers and/or supervisors, technologists, receptionists, schedulers, patient transport, and information technology support staff (on-call) are also critical at all times. Staff in the emergency radiology facility should be aware of the unique workflow and demands of emergency imaging. For example, emergency technologists should have the technical skills to image multiple body parts and perhaps even cover multiple modalities. In addition, technologists should be well versed in patient care with the ability to manage patients who are acutely ill, pregnant patients, and all age ranges, and, technologists should also be highly skilled at workflow management and operational efficiency given the high volume and urgency of ED cases.

Decision Support

Decision support via appropriate communication, informatics, and active radiologist involvement in protocoling is key to any emergency radiology facility. Tracking of studies and protocols can be accomplished via information technology dashboards via the radiology information system or any other electronic dashboard. The decision support conversation incorporates communication of the clinical presentation, physical examination, and laboratory tests, which permits the confirmation of examination appropriateness and selection of optimal examination protocol. The conversation also permits an inquiry regarding possible pregnancy, contrast allergy, and renal function impairment.

Maintaining Quality in Emergency Radiology

There are multiple strategies for maintaining quality in the practice of emergency radiology. Maintaining quality requires maximizing communication, documentation, peer review, and development of collaborative relationships with referring clinical services such as emergency medicine and trauma service.

All emergency radiology procedures and protocols are currently documented and readily available to all staff 24 hours a day 7 days a week online and in hard copy. Cross-sectional imaging protocols are also loaded into scanners. All staff are trained and familiar with emergency radiology procedures and protocols. Radiologists are also responsible for correct protocol implementation and adherence. Monitoring of all cross-sectional imaging studies in our institution has been effective. An emergency radiologist monitors all CT, MR, and ultrasound examinations. By having continuous round-the-clock coverage, CTs on multiple trauma patients

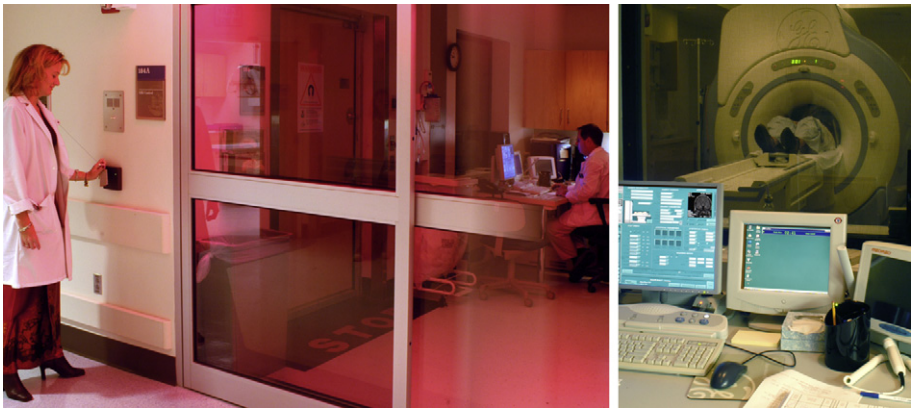

Figure 2. Restricted entry to the magnetic resonance imaging suite with electronic card access. This figure is available in colour online at http://carjonline.org/.

are performed with the radiologist present in the CT control room. Monitoring ensures that the examination is of diagnostic quality and is complete. Monitoring also ensures recognition for the need of postprocessing or if any additional imaging acquisition is needed.

Technologist feedback is also critical for quality assurance and improvement of standards. At our institution, we use an information system , Qatchall, created at our institution, which allows radiologists to report quality assurance issues. Peer-to-peer feedback is also a practice that can result in quality improvement. For example, at our institution, we use a system, Grapevine, created at our institution, that facilitates radiology report peer review in a conference setting.

Management of Transfer Patient Imaging and CD-ROM Import

Currently, many trauma centres and EDs will care for patients who are transferred in with imaging from other facilities on a CD-ROM. There are a multitude of various vendors that facilitate image sharing and CD-ROM import into a local PACS system. There also is evidence that the availability of such systems can decrease reimaging, reduce costs, and limit unnecessary exposure to excess radiation. CD import availability for patients transferred to the emergency department reduces rates of subsequent imaging utilisation by 17% overall and reduces CT utilisation by 16% [3].

Emergency Radiology: Future

Future trends in emergency radiology will include response to an aging population; health care reform; new imaging modalities, such as cardiac CT; the need for radiation dose reduction; and increasing demand for MRI.

Aging Population

The percentage of residents in the United States older than 65 years of age was 11% in 1900 and was 21% in 2010 [4]. Patients older than 65 years of age are hospitalized more frequently and stay in the hospital longer if admitted. Patients older than 65 years of age also visit the ED more often and use 30% of health care funds [5,6].

Figure 3. The reading room at our institution has 6 workstations and a 3-dimensional workstation. This figure is available in colour online at http://carjonline.org/.

Figure 4. Large Picture Archiving and Communication System (PACS) wall monitor for emergency radiology daily conferences and clinical rounds. This figure is available in colour online at http://carjonline.org/.

Health Care Reform

With health care reforms and access to care, it is expected that there will be increased use of EDs, which results in increased volumes in the emergency radiology facility. To reduce costs, emergency imaging will play a role in identifying patients who do not require admission, and quicker diagnoses will lead to shortened hospital stays.

New Imaging Techniques: Coronary CT Angiography

Current strategies to rule out acute coronary syndrome include serial enzymes, electrocardiogram, and stress testing) are inefficient, which results in ED delays, ED overcrowding, and unnecessary admissions. The finding of normal coronary arteries will obviate the need for additional tests and expedite patient discharge. The availability of 64-slice multidetector CT scanners and dual energy–dual source CT scanners will enable coronary CT angiography in the emergency radiology setting. Coronary CT angiography, therefore, may enable earlier and safe triage, which reduces hospital admissions and length of stay compared with the standard ED evaluation.

Dose Reduction of Radiation Exposure in the ED

A significant number of CTs are performed on patients in the ED. More than 70 million CTs are performed annually in the United States. As a result, CTs account for a growing and significant proportion of medical radiation exposure. In a National Center Institute led study, CTs in 2007 alone may have contributed to 29,000 new cancer cases and 15,000 cancer deaths. There are multiple causes for unnecessary CT exposure in patients in the ED (Table 4), therefore, reduction of radiation dose in CT imaging in the emergency setting would be critical; this can be accomplished via improved decision support and use of low-dose CT techniques. Decision support can serve as a gatekeeper to reduce common causes of unnecessary CT radiation exposure in patients in the ED. For instance, decision support can avoid repeating CTs already performed (often at referring hospitals) and limit excessive utilisation of CT. CT techniques that reduce the radiation dose include iterative image reconstruction algorithms.

Table 4
Causes of unnecessary computed tomography (CT) exposure in patients in the emergency department

Repeating CTs that have already been performed (often at a referring hospital)
Performing CTs when results are unlikely to affect patient management
Investigating CTs too frequently (eg, repeated CTs to follow passage of a renal stone)
Performing the wrong imaging examination
Performing incorrect CT protocol from communication failure of true clinical presentation, resulting in a repeated CT
Over investigating via medical imaging (eg, unnecessary noncontrast and delayed scans)

Increased Demand for MR Scanning of Patients in the ED

There is a growing demand for MRIs of patients in the ED. An MRI holds clinical utility in evaluation of traumatic as well as nontraumatic central nervous system emergencies. An MRI is beneficial in the evaluation of acute musculoskeletal injuries, especially in cases with negative or questionable radiographs. To avoid ionizing radiation, MRI also can be used in imaging of acute abdominal conditions in pregnant women and in children.

Summary

In the past 2 decades, emergency radiology has emerged as one of the newest and fastest growing radiology subspecialties. In the past, emergency imaging consisted of radiographic examinations, and patients who required more advanced diagnostic imaging were admitted for hospitalization. Today, with the ready availability of cross-sectional imaging with CT, MRI, and ultrasound, the emergency radiology facility has become the acute diagnostic imaging centre. U.S. emergency departments have experienced an explosive growth of emergency imaging, especially with emergency CT. However, the use of emergency cross-sectional imaging can expedite patient care as well as prevent unnecessary hospital admissions and unnecessary emergency surgery. A successful emergency imaging facility must be carefully designed and managed to provide the quality imaging resources required for the predicted increase in volume of emergency patient visits. Also predicted is an increase in demand for 24 hours per day, 7 days per week emergency imaging services as well as demands of an increase in emergency cardiac imaging and emergency MR, and in measures to decrease CT radiation exposure.

Acknowledgements

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