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WHAT'S NEW IN INTENSIVE CARE

Intensive Care Medicine in 2050: the future of medical imaging

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Medical history and clinical examination relying on inspection, palpation, percussion and auscultation were the first essential tools of medical investigation. During the early years of the twenty-first century, medical imaging with X-rays, ultrasound, computed tomography (CT) scan and magnetic resonance imaging (MRI) became essential parts of care in intensive care medicine. Imaging has further evolved in 2050. This huge progress is owing to the miniaturization of devices, decreased acquisition time, and technology improvements allowing imaging to move to the patient bedside [1]. Morbidity and mortality associated with transportation of critically ill patients to the imaging department no longer exist.

Ultrasonography

Ultrasonography performed by the intensivist is the indispensable imaging tool and has replaced the stethoscope [2]. The intensivist masters cardiac, general ultrasound (US) and guidance of invasive procedures. Every intensivist carries a pocket sonography probe in order to diagnose and guide the treatment of patients in and out of the intensive care unit (ICU) [3, 4]. The ultrasonography probe is the shape of a pencil with a wide frequency range (1–10 MHz) and wireless connection to a cellular phone and/or the operator's watch. The image may be projected onto the cellular screen, to a heads-up display worn by the clinician, or to a larger screen for training or conferencing purposes. Ultrasonography images are shared real-time over internet connections for remote expert level consultation. The system has 3D capability to allow re-construction of structures from the standard scan (Fig. 1).

Peripheral, central, arterial extra corporeal membrane oxygenation catheters and other invasive procedures are performed safely using the modern guiding device [5] with continuous visualization of the needle from skin penetration to target position. Intensivists routinely perform paracentesis, thoracentesis, pericardiocentesis, lumbar puncture, pleural device insertion, suprapubic cystostomy, pyelonephrostomy, and drainage of abdominal collections using ultrasonography guidance.

Coupled laser-stimulated US allows the exploration of tissues without contact. Laser stimulation induces subtle warming of explored tissues, which is reflected back to the surface and detected by a second laser device [1]. Functional assessment of renal function is performed after intravenous infusion of ultrasonic contrast media. There is no longer any need to compute the classical creatinine clearance. Daily chest assessment in patients with lung disease is performed at the bedside with the same probe connected by Wi-Fi to the virtual extra-large screen of the cardiac monitor [6].

Decentralized hard disks allow downloading of large quantities of ultrasonography data that can be correlated with information from MRI, CT, or electrical impedance tomography [6]. Tele-ultrasonography is standard [7], allowing the review of complex cases via video conference with expert radiologists. This occurs during bedside rounds or in formal conferences as valuable opportunities to review challenging cases with specialists located overseas.

X-rays

Owing to its low sensitivity, and despite decreased radiation dose, conventional X-ray imaging is no longer used in ICU. Previous experience with CT scanner relocation in the operating room to perform vertebroplasty [8] or nodule ablation [9] has been extended to the ICU. By 2050, a dedicated low dose CT-scan [10] will be present

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in every ICU allowing accurate and total body imaging of the most severe ICU patients (i.e. receiving extracorporeal therapies) in a safe environment. In cases of bleeding requiring embolization, the patient is not moved out of the ICU, but the interventional imaging physician provides care in the ICU at the bedside.

MRI

Magnetic resonance imaging has replaced CT scanning as the first method for brain imaging. The size and weight of MRI machines have decreased (to less than 100 kg) owing to lessened magnetic fields (no more than 0.1 Tesla). As a consequence, neither a Faraday cage nor an expensive cooling system using liquid helium are mandatory and these MRI machines are part of ICU equipment and can eventually be moved to the bedside. Open MRI machines with a limited region of interest permit the assessment of patients treated with the most complex supportive therapies (Fig. 1). The performance of these machines is sufficient to diagnose sub-arachnoid hemorrhage, encephalitis, and ischemic stroke allowing indicated thrombolytic therapy to be administered without delay. Due to improvements in computer processing and signal acquisition, the time required for image acquisition is similar to CT. The MRI machine performs rapid high-quality body imaging (heart, lung, abdominal, vascular) which, when coupled with novel contrast agents, permits high-quality pulmonary angiography images. MRI also permits the diagnosis of secondary cholangitis and can assess obstructive uropathy. Injection of contrast media agents is used to demonstrate the site of biliary duct leakage after surgery [11]. Rapid interpretation of MRI imaging is the responsibility of radiologists connected to the ICU team via a telemedicine connection for immediate integration of the results by the bedside team.

Fig. 1 Open MRI with limited magnetic field allowing the safe performing of imaging of patients with invasive procedures

Contrast media agents

Nanotechnology and engineering have succeeded in elaborating high-performance and well-tolerated contrast media agents. Short and long half-life products are available. These products are retained during a short or long period within the targeted organ without side effects, and permit assessment of organ perfusion at the bedside. They are linked to intravenously administered therapies such as antibiotics, targeted chemotherapy, and immunotherapy [12]. Therefore, penetration of these contrast media-coupled therapies within target organs (lung, kidney, liver, spleen, brain, heart, bones) can be assessed in real time. The course, localization, local uptake, and fate of therapies are monitored by imaging; thus, there are no longer requirements to assess plasma levels of these treatments.

Pet scan-MRI and other hybrid multimodality imaging devices

Assessment of the source of disseminated infectious processes does not require iterative microbiological samples and multiple imaging investigations. Work-up of infectious processes such as infective endocarditis is rapidly determined using positron emission tomography (PET) scanning. Hybrid imaging relying on coupling two complementary imaging modalities (e.g., MRI and PET scan) accurately identifies the focus of infection and the efficacy of anti-infective treatment.

The availability of most imaging modalities in the ICU of 2050 provides autonomy to the ICU team but requires inclusion of advanced medical imaging training into the ICU resident's formation course. Expert level radiology consultation is immediately available 24/7 via telemedicine connections allowing full integration of intensivist capability with high-level radiologist image interpretation.

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