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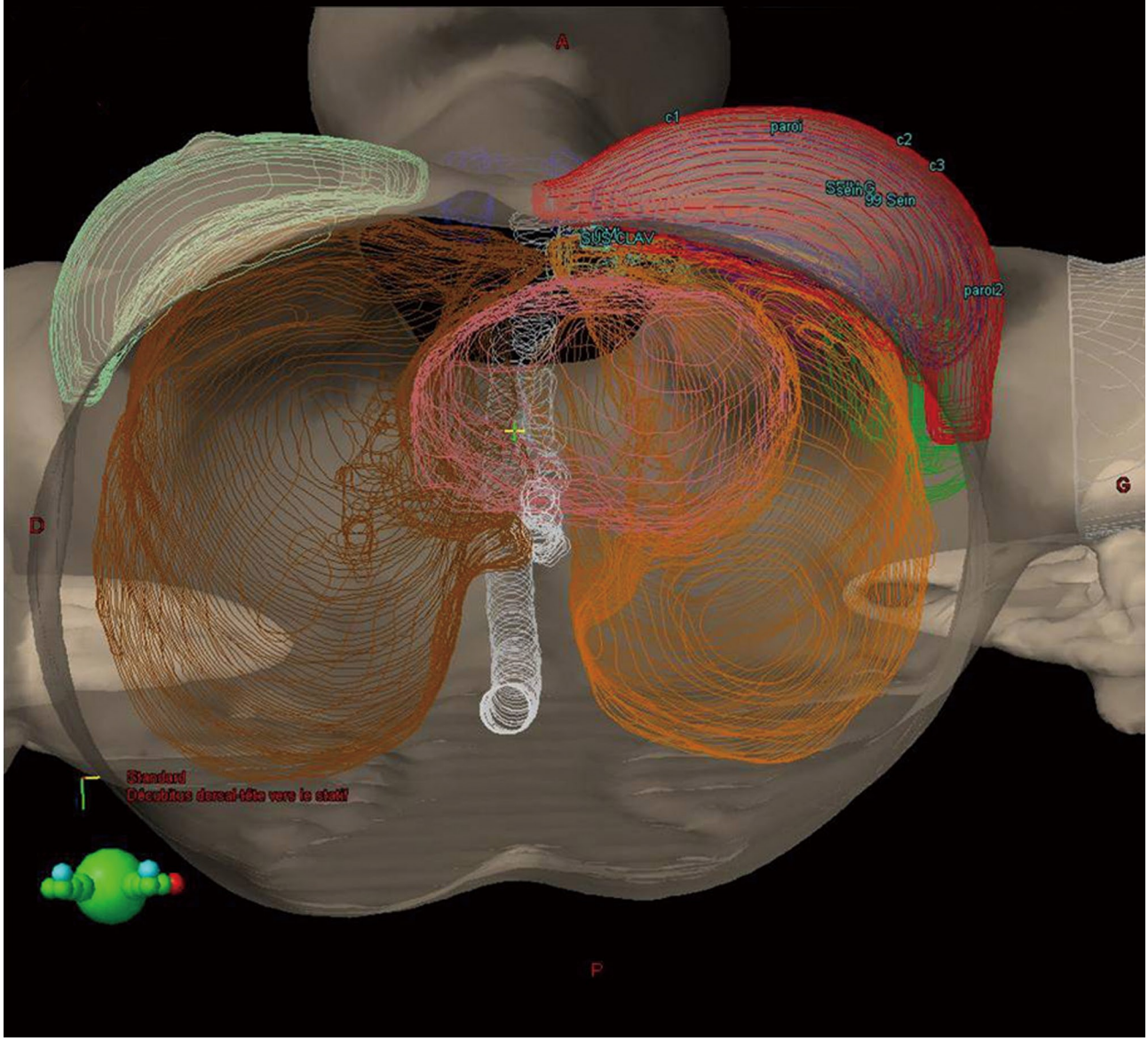
3D reconstruction of defined target volumes and the organs of risk. The left breast is shown in red, heart in pink, lungs in brown and yellow, thyroid in blue, spinal cord in white.



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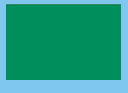

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EDITORIAL

Computed tomography imaging of acute neck inflammatory processes

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Abstract

Early diagnosis and management of neck infections and inflammatory processes is a common challenge for emergency and ear, neck and throat physicians, as well as radiologists. Emergency neck infections are diverse in their presentation, ranging from a transient enlargement of a lymph node to a rapidly spreading necrotizing fasciitis. Symptoms and signs, with the clinical history, usually suggest the diagnosis. But complex neck anatomy and sometimes limited physical examination can obscure and delay diagnosis, thus the need for an appropriate imaging exam and correct interpretation. In this pictorial review, we will consider common neck acute inflammatory processes that may be encountered in the emergency room and discuss some of their salient imaging findings.

Key words: Neck infections; Inflammatory; Computed tomography

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INFECTIONS OF THE LYMPH NODES

A variety of infectious and non-infectious processes may cause enlargement of cervical lymph nodes, which is referred to as "reactive". Cervical adenitis denotes an inflammation of the lymph nodes of the neck due to an infectious process (Figure 1A). Suppurative adenitis indicates an infected node that has undergone liquefaction necrosis (Figure 1B). The likelihood of developing cervical adenitis, especially suppurative forms, decreases with age, although the incidence of suppurative adenitis is increasing in older patients[1,2].

The most common cause of cervical lymph node enlargement, which is most frequent in children, is viral infections of the upper respiratory tract[3,4]. Bacterial infections are the most common cause of suppurative cervical adenitis with staphylococcus aureus and Group A streptococcus being the most common etiologic agents[5,6].

Computed tomography (CT) suggests early involvement of a lymph node by its homogeneous enlargement, loss of the fatty hilum and increased enhancement of the involved lymph node on CT (Figure 1A). Reticulation of the adjacent fat surrounding a suppurative lymph

node or the presence of a circumferential rim of soft tissue may be helpful in differentiating an inflammatory etiology as the cause of the abnormal node as opposed to metastases.

Cat-scratch disease

Cat-scratch disease (CSD) is caused by the bacteria *Bartonella henselae* and usually presents within 3-10 d following contact with a cat[7]. It is a very common cause of enlarged cervical lymph nodes in children.

CT usually demonstrates a unilateral clumped group of enlarged lymph nodes clustered in the primary eschelon drainage of the site of contact.

Tuberculous lympadenitis

Lymphadenitis is the most common form of head and neck tuberculosis. There is a significant increase in the prevalence of tuberculosis in industrialized countries due to the acquired immune deficiency syndrome epidemic, drug abuse and increased migration[8,9]. Involvement is commonly bilateral and most frequently involves the internal jugular, posterior triangle and supraclavicular nodes.

CT usually reveals enlarged lymph nodes with homogeneous contrast enhancement. As the disease evolves, central necrosis can be detected as foci of low density associated with rim enhancement (Figure 2). Healed lesions and nodes may show calcifications.

DEEP NECK INFECTIONS

Retropharyngeal space infections

In adults, infection of the retropharyngeal space is usually due to a penetrating injury. Gram positive cocci are the most common pathogen implicated in such cases[10]. In children, however, retropharyngeal space infections are most commonly due to an upper respiratory tract infection. The causal organism is usually Hemophilus influenzae. The affected patient often presents with fever, neck pain, sore throat and neck mass[11].

On CT, retropharyngeal cellulitis is identified by symmetric low attenuation in the retropharyngeal space (Figure 3) with some anterior displacement of the posterior wall of the pharynx, usually not exceeding few millimeters. Retropharyngeal suppurative adenitis is identified by enlarged paramedian retropharyngeal lymph nodes that contain a low attenuation center (Figure 4). A retropharyngeal abscess is identified by a low attenuation fluid collection that causes substantial anterior displacement of the posterior wall of the pharynx from the pre-vertebral muscles (Figure 5). Retropharyngeal abscesses usually do not have a thick enhancing wall.

On magnetic resonance (MR), enlarged retropharyngeal nodes show intermediate signal intensity on T1-weighted images and strong contrast-enhancement. Rim enhancement indicates the presence of suppurative lymphadenitis. On T2-weighted images, the inflamed nodes show high signal intensity. Soft tissue thickening as a result of cellulitis also shows strong contrast enhancement and high signals on T2-weighted images.

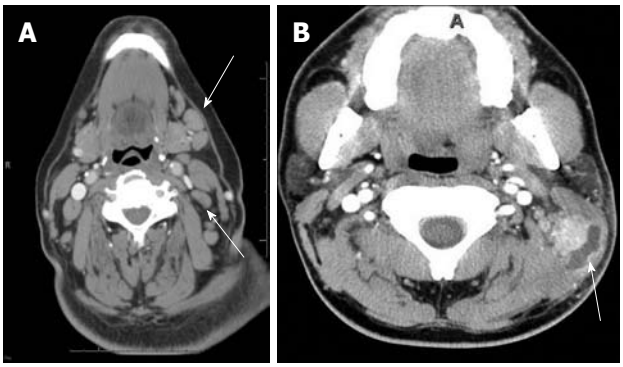

Figure 1 Cervical and suppurative adenitis. A: Axial contrast-enhanced computed tomography (CT) shows homogenous enlargement of multiple enlarged to borderline sized lymph nodes (arrows), in a patient with neck pain consistent with cervical adenitis; B: Axial contrast-enhanced CT shows a suppurative cervical lymph node (arrow) with surrounding soft tissue edema.

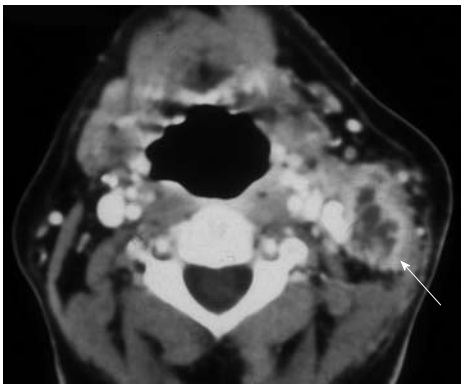

Figure 2 Tuberculous lymphadenitis. Axial contrast enhanced CT shows a necrotic suppurative lymph node in a patient with tuberculosis (arrow).

Figure 3 Retropharyngeal space edema. There is symmetric low attenuation in the retropharyngeal space (arrow). There is associated left jugular vein thrombosis (arrowhead).

Tonsillar abscess

In contrast to acute tonsillitis, which is more common in children, a tonsillar abscess is more common in young adults. The average age is 25 years with more than 65%

Figure 4 Suppurative adenitis of the left retropharyngeal lymph (arrow).

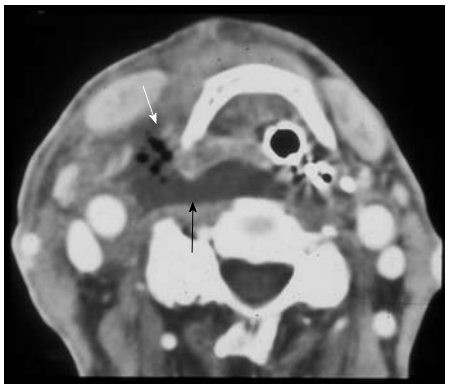

Figure 5 Retropharyngeal space abscess. Contrast-enhanced CT shows fluid (black arrow) and gas (white arrow) in the retropharyngeal space.

of patients falling between 20-40 years. Sore throat, dysphagia, fever and trismus are the usual clinical symptoms. Almost all patients have a history of recurrent pharyngitis. Management typically includes incision and drainage with antibiotic coverage[12].

CT shows an enhancing mass in the tonsillar fossa that may or may not show pus formation (Figure 6). Extension into the parapharyngeal space may involve the medial pterygoid muscles and may lead to trismus. The inflammatory process may spread posterolaterally into the carotid sheath with possible jugular vein thromobosis or carotid artery erosion.

Parapharyngeal abscess

An abscess in the parapharyngeal space may arise from direct extension of infection from the pharynx through the pharyngeal wall, as a consequence of odontogenic infection, local trauma, and occasionally peritonsillar abscess[13]. Diabetes is the most common systemic condition predisposing one to parapharyngeal abscess.

Patients often present with fever, sore throat and neck swelling. Erythema, odynophagia, and dysphagia often accompany such infections[14]. Trismus is most commonly associated with anterior compartment abscesses.

Contrast-enhanced CT scanning is the imaging examination of choice to diagnose parapharyngeal abscess.

Figure 6 Tonsillar abscess. Contrast-enhanced axial CT demonstrates an abscess involving the right tonsil (arrow).

Figure 7 Parapharyngeal space abscess. Contrast-enhanced CT shows a low attenuation fluid collection with peripheral enhancement in the left parapharyngeal space (arrow).

CT shows a single or multiloculated low-density lesion with an air and/or fluid center (Figure 7) with occasional enhancement of the abscess wall.

Cellulitis and necrotizing fascitis

Cellulitis is a bacterial infection of the skin. Necrotizing fasciitis is a rapidly spreading bacterial infection of the soft tissue that can quickly become a life-threatening condition. It is commonly caused by either streptococcal or polymicrobial infections. Patients with necrotizing fasciitis are best managed in the ICU and are typically treated with parenteral antibiotics and frequent surgical debridement[15].

CT imaging will reveal non-specific findings of diffuse reticulation of subcutaneous fat along with thickening and enhancement of the platysma (Figure 8). One may also find multiple abscesses extending along the fascial planes. Presence of gas within the soft tissue in the absence of prior surgery or radiation therapy is pathognomonic for necrotizing fasciitis.

Bezold abscess

A Bezold abscess is a rare complication of otomastoiditis with necrosis of the mastoid tip and spread of infection from bone to the adjacent soft tissue. Inflammatory

Figure 8 Cervical cellulitis. Contrast-enhanced CT scan shows diffuse reticulation of subcutaneous fat with thickening and enhancement of the platysma (arrow).

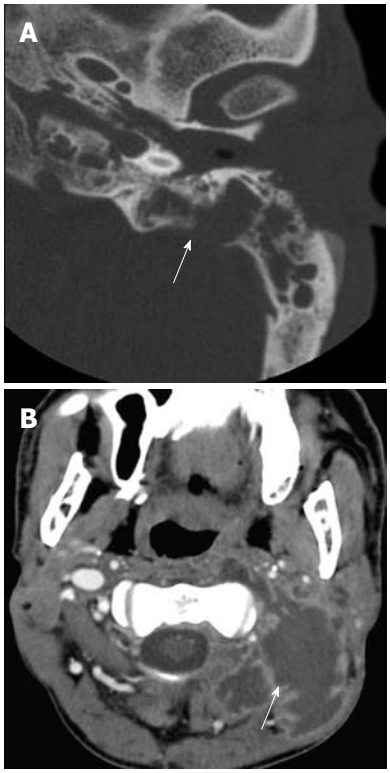

Figure 9 Bezold abscess. A: Axial contrast-enhanced CT shows opacification of the mastoid air cells with associated bone erosion indicating an aggressive inflammatory process (arrow); B: The soft tissue algorithm demonstrates a multiloculated abscess involving the paraspinal musculature (arrow).

collections may course along the plane of the sternocleidomastoid muscle to the lower neck. If left untreated, the abscess may spread as far as the larynx and mediastinum, which results in a poor prognosis. Clinically, patients present with fever, neck pain, restricted neck motion, and otalgia[16,17].

On CT imaging, there is usually unilateral opacification of the middle ear and mastoid cavities, often associated with bone erosion, especially of the mastoid tip (Figure 9A). The abscess involves the adjacent musculature surrounding the mastoid and extends inferiorly (Figure 9B)[18].

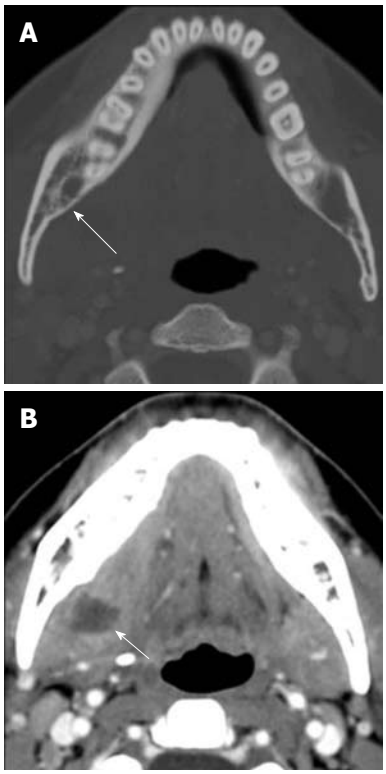

Figure 10 Floor of mouth abscess after dental extraction. A: The bone algorithm shows focal cortical erosion in the region of the right 2nd molar, after the tooth extraction (arrow); B: Axial contrast-enhanced CT shows abscess extending into the right sublingual space (arrow).

SUBLINGUAL SPACE INFECTIONS

Sublingual space abscess

Abscesses originating in this space are usually due to sublingual or submandibular duct stenosis or calculus disease. Dental infection or mandibular osteomyelitis, however, may also extend into the sublingual space (SLS). The most commonly encountered organisms in SLS abscess formation are *Staphylococcus aureus* and *Streptococcus viridans*.

Clinically, patients with SLS abscess usually present with pain, tenderness and swelling in the anterior floor of the mouth. There may be a history of salivary colic, recent dental disease or dental manipulation.

CT shows an enhancing mass involving the SLS associated with subcutaneous streaking and thickening of the platysmus muscle. The genioglossus-geniohyoid complex is often displaced medially or across the midline (Figure 10). If a submandibular component is present, the infectious process may track into the parapharyngeal space. Infection may also spread to the medial pterygoid or masseter muscles.

Ludwig's angina

Ludwig's angina denotes cellulitis of the floor of the mouth with infection of the submental, sublingual, and submandibular space. This infection is usually due to streptococcus or staphylococcus species. Patients usually present with pain, tenderness and swelling of the mouth floor. The infection is usually precipitated by an odonto-

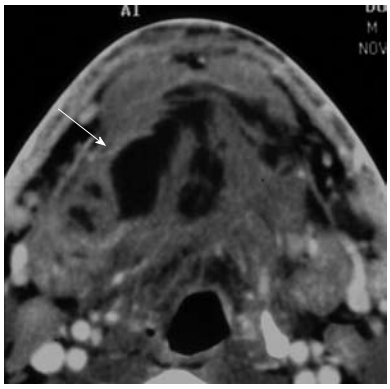

Figure 11 Ludwig's angina. Contrast enhanced CT shows multiple abscess (arrow) in the sublingual space.

genic infection[19,20]. In neglected cases, Ludwig's angina may spread inferiorly through fascial planes into the mediastinum, with some patients presenting with chest pain.

Since the tongue can rapidly become posteriorly displaced in this condition, securing a patient's airway is a priority[21].

Contrast-enhanced CT shows swelling of the floor of the mouth (Figure 11) frequently associated with streaky changes in the adjacent subcutaneous fat and thickening of the overlying platysmus muscle. Enlargement of the submental or submandibular lymph nodes may also be seen, with pus or gas formation present in late cases.

Contrast enhanced MR images, if performed, may show a thickened floor of the mouth with strong enhancement. On T2-weighted images, diffuse high signals are evident in the floor of the mouth and adjacent soft tissues.

CALCIFIC TENDINITIS

Calcific tendinitis is a benign inflammatory condition caused by deposition of hydroxyapatite in the tendon fibers of the longus colli muscles[22]. Patients present clinically with either sudden onset or subacture pain in the neck and throat worsened by head movement and swallowing[23]. Due to its rare occurrence, it is often mistaken, clinically, for traumatic injury, retropharyngeal abscess, or infectious spondylitis, causing patients to frequently undergo unnecessary tests and treatment. The condition, however, is self-limited and resolves after 1-2 wk upon calcium resorption.

CT imaging may show extensive soft tissue swelling between C1 through C4 with amorphous calcific deposits anterior to C1 and C2[24], with pre-vertebral edema, which are findings that may suggest retropharyngeal space infection (Figure 12).

MRI, if performed, will demonstrate a signal void anterior to C1 and C2 representing an amorphous calcification. Additionally, MR may demonstrate marrow edema in adjacent vertebrae.

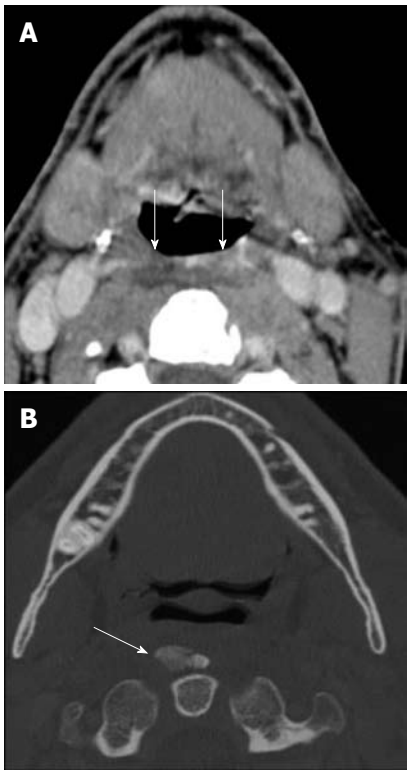

Figure 12 Calcific tendinitis. A: Axial contrast enhanced CT of the neck demonstrates retropharyngeal space edema (arrows); B: The bone algorithm shows an ossific mass anterior to the dens confirming that the edema in the retropharyngeal space is due to calcific tendinitis (arrow).

INGESTION OF FOREIGN BODY

The majority of swallowed pharyngeal and esophageal foreign bodies take place in the pediatric population[25]. Senile, stuperous and psychiatrically ill adult patients are also prone to swallowing a variety of foreign objects. The ingested foreign bodies usually lodge in areas of normal anatomic narrowing in the cricopharyngeus area, the aortic arch or the distal esophagus. Sharp objects may perforate the pharynx or esophagus and may result in abscess formation in the adjacent spaces, such as the retropharyngeal space. Non-contrast CT confirms the presence of an ingested foreign body. Contrast-enhanced CT will demonstrate the site and level of the resultant inflammation or abscess.

CONCLUSION

Infectious and inflammatory processes of the neck are frequently encountered situations in the emergency room, with diverse clinical presentation and symptomatology, often with limited physical exam due to complex neck anatomy and limited accessibility to deep neck tissues. CT imaging has become a necessary tool for the diagnosis of neck inflammatory processes, localizing the site and extension of the process and helping in decision making for appropriate surgical or medical intervention. In this pictorial, we review the most frequently encountered situations and we discuss their usual CT findings.

REFERENCES

1 **Randall TD**, Carragher DM, Rangel-Moreno J. Development of secondary lymphoid organs. *Annu Rev Immunol* 2008; **26**: 627-650
2 **Long SS**, Pickering LK, Prober CG. Principles and practice of pediatric infectious diseases. 3rd ed. Churchill Livingstone: Elsevier, 2008
3 **Peters TR**, Edwards KM. Cervical lymphadenopathy and adenitis. *Pediatr Rev* 2000; **21**: 399-405
4 **Rudolph CD**, Rudolph AM, Hostetter MK, Lister G, Siegel NJ, editors. Rudolph's Pediatrics. 21 ed. New York: McGraw Hill Medica, 2003
5 **Baker CJ**. Group B streptococcal cellulitis-adenitis in infants. *Am J Dis Child* 1982; **136**: 631-633
6 **Dajani AS**, Garcia RE, Wolinsky E. Etiology of cervical lymphadenitis in children. *N Engl J Med* 1963; **268**: 1329-1333
7 **Heyman DL**, editor. Control of communicable diseases manual. 19th ed. American Public Health Association, 2008
8 **Frieden TR**, Sterling TR, Munsiff SS, Watt CJ, Dye C. Tuberculosis. *Lancet* 2003; **362**: 887-899
9 **Field MJ**. Tuberculosis in the Workplace. Washington: National Academy Press, 2001
10 **Brook I**. Microbiology and management of peritonsillar, retropharyngeal, and parapharyngeal abscesses. *J Oral Maxillofac Surg* 2004; **62**: 1545-1550
11 **Craig FW**, Schunk JE. Retropharyngeal abscess in children: clinical presentation, utility of imaging, and current management. *Pediatrics* 2003; **111**: 1394-1398
12 **Johnson RF**, Stewart MG. The contemporary approach to diagnosis and management of peritonsillar abscess. *Curr Opin Otolaryngol Head Neck Surg* 2005; **13**: 157-160
13 **Glynn F**, Skinner LJ, Riley N, Donnelly M. Parapharyngeal abscess in an insulin dependant diabetic patient following an elective tonsillectomy. *J Laryngol Otol* 2007; **121**: e16
14 **Page C**, Biet A, Zaatar R, Strunski V. Parapharyngeal abscess: diagnosis and treatment. *Eur Arch Otorhinolaryngol* 2008; **265**: 681-686
15 **Miller LG**, Perdreau-Remington F, Rieg G, Mehdi S, Perlroth J, Bayer AS, Tang AW, Phung TO, Spellberg B. Necrotizing fasciitis caused by community-associated methicillin-resistant Staphylococcus aureus in Los Angeles. *N Engl J Med* 2005; **352**: 1445-1453
16 **Smouha EE**, Levenson MJ, Anand VK, Parisier SC. Modern presentations of Bezold's abscess. *Arch Otolaryngol Head Neck Surg* 1989; **115**: 1126-1129
17 **Castillo M**, Albernaz VS, Mukherji SK, Smith MM, Weissman JL. Imaging of Bezold's abscess. *AJR Am J Roentgenol* 1998; **171**: 1491-1495
18 **Gaffney RJ**, O'Dwyer TP, Maguire AJ. Bezold's abscess. *J Laryngol Otol* 1991; **105**: 765-766
19 **Weed HG**, Forest LA. Deep neck infection. In: Cummings CW, Flint PW, Harker LA, Haughey BH, Richardson MA, Robbins KT, Schuller DE, Thomas JR, editors. Otolaryngology: head and neck surgery. 4th ed. Philadelphia: Elsevier Mosby, 2005: 2515-2524
20 **Marple BF**. Ludwig angina: a review of current airway management. *Arch Otolaryngol Head Neck Surg* 1999; **125**: 596-599
21 **Bross-Soriano D**, Arrieta-Gómez JR, Prado-Calleros H, Schimelmitz-Idi J, Jorba-Basave S. Management of Ludwig's angina with small neck incisions: 18 years experience. *Otolaryngol Head Neck Surg* 2004; **130**: 712-717
22 **Vieira F**, Allen SM, Stocks RM, Thompson JW. Deep neck infection. *Otolaryngol Clin North Am* 2008; **41**: 459-483, vii
23 **Eastwood JD**, Hudgins PA, Malone D. Retropharyngeal effusion in acute calcific prevertebral tendinitis: diagnosis with CT and MR imaging. *AJNR Am J Neuroradiol* 1998; **19**: 1789-1792
24 **Haun CL**. Retropharyngeal tendinitis. *AJR Am J Roentgenol* 1978; **130**: 1137-1140
25 **Digoy GP**. Diagnosis and management of upper aerodigestive tract foreign bodies. *Otolaryngol Clin North Am* 2008; **41**: 485-496, vii-viii

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TOPIC HIGHLIGHT

Hui-Xiong Xu, MD, PhD, *Series Editor*

Contrast-enhanced ultrasound of the pancreas

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Abstract

The introduction of contrast-enhanced ultrasonography (CEUS) has led to major improvements in the diagnostic capabilities of ultrasound (US). The innovative use of CEUS for study of the pancreas has created the need for a definition of the most frequent dynamic features of solid and cystic masses. CEUS is less expensive compared to computed tomography and magnetic resonance imaging and is able to significantly improve the accuracy of US, allowing better characterization and staging of pancreatic pathologies.

Key words: Contrast-enhanced ultrasonography; Ultrasound; Pancreatic diseases

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INTRODUCTION

Ultrasound (US) is often the first mode of examination in patients with pancreatic disease. The introduction of contrast-enhanced ultrasonography (CEUS) has led to great improvements in the diagnostic capabilities of US[1].

CEUS takes advantage of its special features: the high contrast and spatial resolution, the use of a blood-pool microbubble contrast medium and the real-time, dynamic evaluation of tumor enhancement, filtering the background tissue signals[1-3]. CEUS is a sensitive imaging method for evaluating the vascularization of pancreatic lesions both solid and cystic[2-7]. The innovative use of CEUS for pancreatic study creates the need for a definition of the most frequent dynamic features of solid and cystic masses.

To overcome subjectivity, the use of quantification software could be suggested for the characterization of pancreatic lesions during CEUS study, as recently reported in the literature[8]. Its high capability in showing tumoral microcirculation also makes CEUS accurate in the study of neoangiogenesis[9]. Interest in the use of CEUS for noninvasive prognostic stratification of pancreatic adenocarcinoma and for the evaluation of chemotherapeutic effects is documented in the literature[10-13].

CEUS is less expensive compared to computed tomography (CT) and magnetic resonance imaging (MRI) and can also be used in patients with renal failure[1,14]. CEUS is able to significantly improve the accuracy of US, allowing a better characterization and staging of pancreatic pathologies[2-7].

TECHNICAL BACKGROUND AND CONTRAST MEDIA

CEUS is the only imaging method that allows a real-

time evaluation of the enhancement during the dynamic phases. Harmonic microbubble (MB)-specific imaging with a low acoustic US pressure (Mechanical index, < 0.2) is required for a dynamic CEUS examination. All the background tissue signals are filtered and the vascular enhancement signals are only related to the harmonic responses of the MBs. A 2.4 mL bolus of second-generation contrast agent, constituted by sulphur hexafluoride filled microbubbles with a phospholipid peripheral shell (SonoVue®, Bracco, Milan, Italy), is injected i.v. followed by a 5 mL bolus of saline solution. A real-time evaluation of the enhancement is possible, maintaining the same scanning frame rate as in the previous conventional B-mode examination. Dynamic observation of the contrast-enhanced phases (arterial, portal/venous and late phases) begins immediately after the injection of the microbubbles[15].

These typical features of CEUS make this method very accurate in perfusion studies, allowing the visualization of the pancreatic lesion microvasculature[2,7]. Some major limitations are the occasionally restricted image resolution of deep regions and the poor sonographic visualization of the gland due to overlying abdominal gas or to large amounts of abdominal fat[1,2].

CLINICAL APPLICATIONS

Inflammatory diseases

Acute pancreatitis: Acute focal pancreatitis, even when supported by clinical data, can cause problems of differential diagnosis in respect to neoplastic lesions[16,17]. A mild acute focal pancreatitis appears as a homogeneously hypoechoic focal enlargement of the gland in conventional US[16,17], and hypervascularized after the administration of contrast agent[17], with different degree of enhancement, resulting in an increased echogenicity in the dynamic phases.

In severe acute pancreatitis, CEUS may improve the detection and delimitation of the necrotic areas, which appear completely avascular[17]. Unfortunately, in the literature there are no studies comparing CEUS with CT or MRI in the evaluation and follow-up of acute pancreatitis. At this moment, CT remains more effective than CEUS, in particular in grading the stage of the disease[18].

Pseudocysts: Pseudocysts can be sequelae of severe acute pancreatitis or can occur in chronic pancreatitis[18]. Characterized by a fibrous wall without an epithelial lining[19], pseudocysts must be differentiated from pancreatic cystic tumors, especially mucinous cystadenomas (MCAs), as they require completely different therapeutic approaches[19]. CEUS has a crucial role in differential diagnosis of pseudocysts and pancreatic cystic tumors, by better evaluating the micro-vascularization of the intralesional inclusions. Even if characterized by a corpuscular and inhomogeneous content in conventional US, pseudocysts are always completely avascular, becoming homogeneously anechoic in CEUS dynamic examination[2].

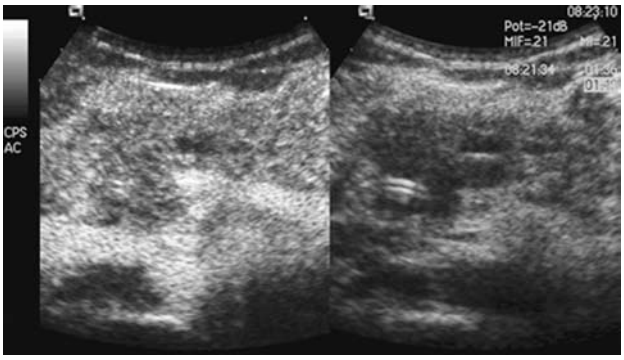

Figure 1 Focal autoimmune pancreatitis. The pancreatic head mass is hypoechoic in conventional ultrasound (US) (right side of the split-screen) and inhomogeneously isovascular in contrast-enhanced US (CEUS) (left side of the split-screen).

Mass forming chronic pancreatitis: Mass-forming chronic pancreatitis usually occurs in patients with a history of chronic pancreatitis[20] and must be differentiated from pancreatic ductal adenocarcinoma[2,7,21], although they are both hypoechoic in conventional US. In CEUS, a mass-forming chronic pancreatitis shows 'parenchymographic' enhancement, characterized by an enhancement pattern always comparable to that of the surrounding pancreatic parenchyma. However, in long-standing chronic inflammatory processes, inhomogeneous hypovascularization of the lesion may be observed, probably owing to the presence of a large amount of fibrosis, and the differential diagnosis becomes more difficult[2,7,21].

Autoimmune pancreatitis: Autoimmune pancreatitis is a particular type of chronic pancreatitis. Characterized by periductal flogosis, mainly sustained by lymphocytic infiltration, with evolution to fibrosis, this pancreatic pathology has a recent pathological definition[22]. The US features resemble those of focal pancreatitis, even if autoimmune pancreatitis more frequently involves the entire gland, with a global enlargement of the pancreas. In all cases, in conventional US the echogenicity is typically markedly reduced and the main pancreatic duct compressed. After the administration of contrast agent, autoimmune pancreatitis shows inhomogeneous a fair, often moderate to marked, enhancement usually followed by a slow washout. These features are related to the thinning of the glandular vessels due to thick lymphocytic infiltration and fibrosis.

CEUS findings may be especially useful in the study of focal forms of autoimmune chronic pancreatitis (Figure 1), in which differential diagnosis in respect to ductal adenocarcinoma is a priority[21,23].

Solid neoplasms

Ductal adenocarcinoma: Pancreatic tumors are classified according to their histological type and grade in the WHO classification[24]. Ductal adenocarcinoma comprises between 80% and 90% of all exocrine tumors of the pancreas. It usually presents as a solid mass with infiltra-

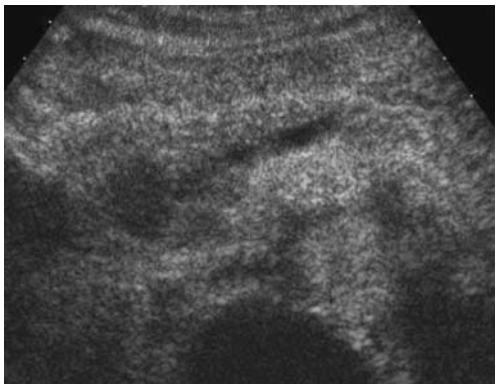

Figure 2 Pancreatic ductal adenocarcinoma. The pancreatic head solid lesion is hypoechoic in CEUS with upstream dilation of the main pancreatic duct.

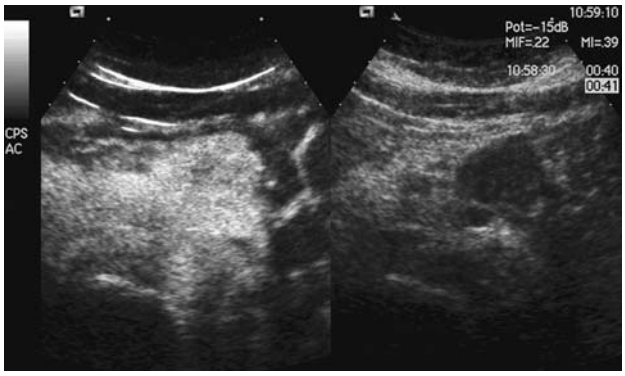

Figure 3 Pancreatic endocrine tumor. The pancreatic body mass is solid and hypoechoic in conventional US (right side of the split-screen) and hypervascular in CEUS (left side of the split-screen).

tive ill-defined growth margins, typically hypoechoic in conventional US. The main pancreatic duct is usually infiltrated and dilated upstream. Doppler studies show poor or no vascularity inside the lesion and the vascular invasion is defined by a focal absence of the echogenic interface of the vessel wall, or by a narrow lumen, with changes in blood flow velocity[25-27]. In CEUS examination, ductal adenocarcinoma typically shows poor enhancement (Figure 2) during all the dynamic phases because of its intense desmoplastic reaction with a relatively poor mean vascular density and perfusion[5,6,23]. The degree of differentiation of the lesion influences its microvascular density[28]: markedly hypovascular masses with very low mean vascular density and perfusion, characterized by avascular areas due to the presence of necrosis, correspond to highly aggressive forms, un-differentiated at pathology, with the poorest prognosis[10].

Loco-regional US staging of ductal adenocarcinoma is very accurate[20] and after the administration of microbubbles both margins and size of the lesion are more visible, improving the detection of vascular infiltration or involvement. In addition, CEUS improves hepatic staging, allowing a higher accuracy in the detection and characterization of distant metastases[18].

Endocrine tumors: Endocrine tumors arise from the neuroendocrine cells of the pancreas and may induce specific clinical syndrome related to the tumor-released hormones (clinically classified as functioning endocrine tumors), or aspecific symptoms resulting from the expansive growth and tumor size [clinically classified as nonfunctioning endocrine tumors (NFETs)][19,29]. In conventional US, they usually present as well-demarked homogeneous hypoechoic masses[30].

Imaging differentiation with ductal adenocarcinoma is fundamental for determining the therapeutic strategy and prognosis[31]. The main pancreatic duct is usually not infiltrated. In Doppler examination, small vessels characterized by arterial flow within the lesion are often detected. However, Doppler "silence" does not exclude the diagnosis of an endocrine tumor owing to the possible small size of the tumor vascular network[15].

In CEUS, endocrine tumors usually appear hypervascular (Figure 3). Voluminous endocrine tumors show rapid and intense enhancement during the early dynamic phases, often with avascular necrotic intralesional areas[31-33]. Rarely, NFETs can also be hypovascularized in imaging, depending on the amount of dense and hyalinized stroma inside the lesion. CEUS improves local and hepatic staging, allowing a higher accuracy in the detection and characterization of distant metastases[15,34].

Metastases: Pancreatic metastases are rare. The most common are from renal cell carcinoma. CEUS may well demonstrate the enhancement of pancreatic metastases from renal cell carcinoma, as they are clearly hypervascular, allowing differential diagnosis against ductal adenocarcinoma. However, their CEUS features cannot be differentiated from those of endocrine tumors. The differential diagnosis is therefore based on the clinical history and symptoms[35,36].

Cystic neoplasms

Serous cystadenoma: Serous cystadenoma (SCA) is a benign lesion[37], usually solitary, without communication with the main pancreatic duct. Typically it presents as a microcystic well-defined lesion, macroscopically characterized by multiple small cysts separated by thin septa orientated to the center[19,38,39]. In 15% of cases a central scar may be present[38]. CEUS improves the US characterization of SCA, showing the enhancement of internal septa, with better identification of the "honeycomb" multilocular architecture of the lesion[17]. The macrocystic type (25%) is divided into the mixed type with large cysts and the unilocular type difficult to be differentiated from MCA[40]. CEUS is helpful not only in the differential diagnosis of SCA, but also in the long-term follow-up of these tumors, which can be conservatively managed in most cases[3].

Mucinous cystic tumors: Mucin-producing tumors of the pancreas may originate either from the peripheral ducts (mucinous cystic tumors) or from the main pan-

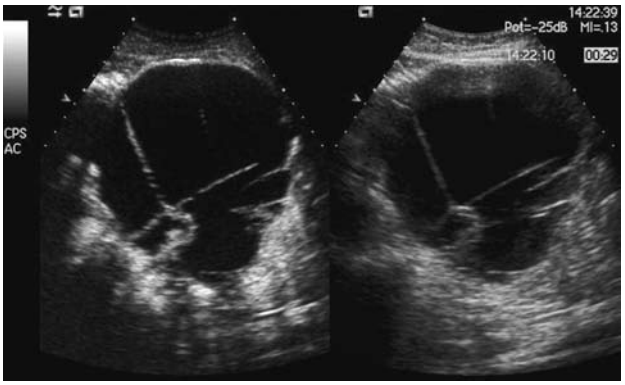

Figure 4 Pancreatic mucinous cystoadenocarcinoma. A voluminous cystic mass is seen in the pancreatic body with septa and nodules in conventional US (right side of the split-screen) and is enhanced in CEUS (left side of the split-screen).

creatic duct and its collateral branches [intraductal papillary mucinous neoplasms (IPMNs)][41].

MCA is a potentially malignant lesion[42], which may degenerate into cystadenocarcinoma[37,39,43]. Imaging characterization is therefore mandatory for a correct therapeutic approach. MCA typically presents as a single round macrocystic lesion, usually located in the body-tail of the gland, without communication with the main pancreatic duct[44,45]. Often large and multilocular, but sometimes unilocular, in conventional US, it is characterized by a dense content resulting from the presence of mucin, and irregular thick wall and internal septa. The malignant degeneration into cystadenocarcinoma is usually characterized by the evidence of parietal nodules. The administration of contrast agent is necessary for a correct diagnosis, i.e. the identification of vascularized inclusions (Figure 4), and for the differential diagnosis between MCA and a pseudocyst[17,46].

IPMNs are cystic tumors of the pancreas recently reported with increasing frequency[6,38,41,47,48]. They are macroscopically characterized by having an intraductal origin and growth[49], with the production of dense mucin that fills the main pancreatic duct (the ductectatic mucin-hypersecreting variant) or with endoluminal papillary proliferation (the papillary-villous variant). The involvement or demonstration of communication with the main pancreatic duct is mandatory for a correct diagnosis[50,51]. They can be divided into 3 types: the central type, with focal or diffuse dilation of the main pancreatic duct; the side branch type, characterized by unilocular or multilocular cystic lesions with grapelike clusters; and the mixed type. US usually demonstrates dilatation of the main pancreatic duct, although MRI still remains the gold standard[51]. CEUS study allows a better detection and characterization of intraductal papillary vegetation, especially in the papillary-villous variant, demonstrating their vascularization[17], thus assisting in the differentiation between benign and malignant lesions[4].

The presence of mural nodules, thick septa and a Wirsung's duct diameter greater than 10 mm are suggestive for malignancy[52].

Solid-pseudopapillary tumor: A solid-pseudopapillary tumor (SPT) is a rare low-grade malignancy of the exocrine pancreas, typically presenting as a large well-defined round mass, without communication with the main pancreatic duct. In conventional US, it shows a inhomogeneous aspect because of hemorrhagic or necrotic or cystic degeneration[19,50]. After the administration of contrast agent, SPT typically shows inhomogeneous enhancement of the thickened peripheral capsule and solid components surrounding cystic and necrotic avascular areas.

TEACHING POINTS

Ultrasound is often the first examination performed in patients with suspicion of pancreatic pathology. In conventional US, the detection of a solid focal hypoechoic pancreatic mass should be considered a ductal adenocarcinoma. The greater accuracy of CEUS compared to conventional US can immediately result in better diagnostic workup and treatment planning. Any solid focal pancreatic mass hypo-enhancing to the normal parenchyma in CEUS has to be considered a ductal adenocarcinoma until otherwise proven. Endocrine tumors are the first differential diagnosis for any focal pancreatic mass hyper-enhancing to the normal parenchyma in CEUS. The presence of vascularized inclusions in a cystic lesion in CEUS excludes the diagnosis of pseudocyst, and the diagnosis of a cystic tumor must be considered. In the presence of any focal pancreatic mass iso-enhancing to the normal parenchyma in CEUS, fine needle aspiration cytology is mandatory for treatment planning.

CONCLUSION

CEUS has improved the characterization of pancreatic tumors, firstly differentiating between solid and cystic lesions. CEUS should always be performed immediately as a complementary imaging method to better characterize a pancreatic lesion detected in conventional US, saving time (faster diagnosis especially for ductal adenocarcinoma) and money (move directly to MRI for cystic tumors).

REFERENCES

1 **Claudon M**, Cosgrove D, Albrecht T, Bolondi L, Bosio M, Calliada F, Correas JM, Darge K, Dietrich C, D'Onofrio M, Evans DH, Filice C, Greiner L, Jäger K, Jong N, Leen E, Lencioni R, Lindsell D, Martegani A, Meairs S, Nolsøe C, Piscaglia F, Ricci P, Seidel G, Skjoldbye B, Solbiati L, Thorelius L, Tranquart F, Weskott HP, Whittingham T. Guidelines and good clinical practice recommendations for contrast enhanced ultrasound (CEUS) - update 2008. *Ultraschall Med* 2008; **29**: 28-44

2 **D'Onofrio M**, Zamboni G, Faccioli N, Capelli P, Pozzi Mucelli R. Ultrasonography of the pancreas. 4. Contrast-enhanced imaging. *Abdom Imaging* 2007; **32**: 171-181

3 **D'Onofrio M**, Megibow AJ, Faccioli N, Malagò R, Capelli P, Falconi M, Mucelli RP. Comparison of contrast-enhanced sonography and MRI in displaying anatomic features of

cystic pancreatic masses. *AJR Am J Roentgenol* 2007; **189**: 1435-1442
4 **Itoh T**, Hirooka Y, Itoh A, Hashimoto S, Kawashima H, Hara K, Kanamori A, Ohmiya N, Niwa Y, Goto H. Usefulness of contrast-enhanced transabdominal ultrasonography in the diagnosis of intraductal papillary mucinous tumors of the pancreas. *Am J Gastroenterol* 2005; **100**: 144-152
5 **Oshikawa O**, Tanaka S, Ioka T, Nakaizumi A, Hamada Y, Mitani T. Dynamic sonography of pancreatic tumors: comparison with dynamic CT. *AJR Am J Roentgenol* 2002; **178**: 1133-1137
6 **Ozawa Y**, Numata K, Tanaka K, Ueno N, Kiba T, Hara K, Morimoto M, Sakaguchi T, Sekihara H, Kubota T, Shimada H, Nakatani Y. Contrast-enhanced sonography of small pancreatic mass lesions. *J Ultrasound Med* 2002; **21**: 983-991
7 **Takeda K**, Goto H, Hirooka Y, Itoh A, Hashimoto S, Niwa K, Hayakawa T. Contrast-enhanced transabdominal ultrasonography in the diagnosis of pancreatic mass lesions. *Acta Radiol* 2003; **44**: 103-106
8 **Kersting S**, Konopke R, Kersting F, Volk A, Distler M, Bergert H, Saeger HD, Grützmann R, Bunk A. Quantitative perfusion analysis of transabdominal contrast-enhanced ultrasonography of pancreatic masses and carcinomas. *Gastroenterology* 2009; **137**: 1903-1911
9 **D'Onofrio M**, Malagò R, Zamboni G, Vasori S, Falconi M, Capelli P, Mansueto G. Contrast-enhanced ultrasonography better identifies pancreatic tumor vascularization than helical CT. *Pancreatology* 2005; **5**: 398-402
10 **D'Onofrio M**, Zamboni GA, Malagò R, Mantovani W, Principe F, Gallotti A, Faccioli N, Falconi M, Capelli P, Mucelli RP. Resectable pancreatic adenocarcinoma: is the enhancement pattern at contrast-enhanced ultrasonography a preoperative prognostic factor? *Ultrasound Med Biol* 2009; **35**: 1929-1937
11 **Tawada K**, Yamaguchi T, Kobayashi A, Ishihara T, Sudo K, Nakamura K, Hara T, Denda T, Matsuyama M, Yokosuka O. Changes in tumor vascularity depicted by contrast-enhanced ultrasonography as a predictor of chemotherapeutic effect in patients with unresectable pancreatic cancer. *Pancreas* 2009; **38**: 30-35
12 **Masaki T**, Ohkawa S, Amano A, Ueno M, Miyakawa K, Tarao K. Noninvasive assessment of tumor vascularity by contrast-enhanced ultrasonography and the prognosis of patients with nonresectable pancreatic carcinoma. *Cancer* 2005; **103**: 1026-1035
13 **Kobayashi A**, Yamaguchi T, Ishihara T, Tadenuma H, Nakamura K, Saisho H. Evaluation of vascular signal in pancreatic ductal carcinoma using contrast enhanced ultrasonography: effect of systemic chemotherapy. *Gut* 2005; **54**: 1047
14 **Faccioli N**, D'Onofrio M, Comai A, Cugini C. Contrast-enhanced ultrasonography in the characterization of benign focal liver lesions: activity-based cost analysis. *Radiol Med* 2007; **112**: 810-820
15 **D'Onofrio M**, Mansueto G, Falconi M, Procacci C. Neuroendocrine pancreatic tumor: value of contrast enhanced ultrasonography. *Abdom Imaging* 2004; **29**: 246-258
16 **Lorén I**, Lasson A, Fork T, Genell S, Nilsson A, Nilsson P, Nirhov N. New sonographic imaging observations in focal pancreatitis. *Eur Radiol* 1999; **9**: 862-867
17 **D'Onofrio M**, Zamboni G, Malagò R, Martone E, Falconi M, Capelli P, Mansueto G. Pancreatic pathology. In: Quaia E, editor. Contrast media in ultrasonography. Berlin: Springer-Verlag, 2005: 335-347
18 **Faccioli N**, Crippa S, Bassi C, D'Onofrio M. Contrast-enhanced ultrasonography of the pancreas. *Pancreatology* 2009; **9**: 560-566
19 **Procacci C**, Biasiutti C, Carbognin G, Capelli P, El-Dalati G, Falconi M, Misiani G, Ghirardi C, Zamboni G. Pancreatic neoplasms and tumor-like conditions. *Eur Radiol* 2001; **11** Suppl 2: S167-S192
20 **Kim T**, Murakami T, Takamura M, Hori M, Takahashi S, Nakamori S, Sakon M, Tanji Y, Wakasa K, Nakamura H. Pancreatic mass due to chronic pancreatitis: correlation of CT and MR imaging features with pathologic findings. *AJR Am J Roentgenol* 2001; **177**: 367-371
21 **D'Onofrio M**, Zamboni G, Tognolini A, Malago R, Faccioli N, Frulloni L, Pozzi Mucelli R. Mass-forming pancreatitis: value of contrast-enhanced ultrasonography. *World J Gastroenterol* 2006; **12**: 4181-4184
22 **Furukawa N**, Muranaka T, Yasumori K, Matsubayashi R, Hayashida K, Arita Y. Autoimmune pancreatitis: radiologic findings in three histologically proven cases. *J Comput Assist Tomogr* 1998; **22**: 880-883
23 **Numata K**, Ozawa Y, Kobayashi N, Kubota T, Akinori N, Nakatani Y, Sugimori K, Imada T, Tanaka K. Contrast-enhanced sonography of autoimmune pancreatitis: comparison with pathologic findings. *J Ultrasound Med* 2004; **23**: 199-206
24 **Klöppel G**, Schlüter E. Pathology of the pancreas. In: Baert AL, Delorme G, Van Hoe L, editors. Radiology of the pancreas. 2nd ed. Berlin: Springer-Verlag, 1999: 69-100
25 **Bertolotto M**, D'Onofrio M, Martone E, Malagò R, Pozzi Mucelli R. Ultrasonography of the pancreas. 3. Doppler imaging. *Abdom Imaging* 2007; **32**: 161-170
26 **Koito K**, Namieno T, Nagakawa T, Hirokawa N, Ichimura T, Syonai T, Yama N, Someya M, Nakata K, Sakata K, Hareyama M. Pancreas: imaging diagnosis with color/power Doppler ultrasonography, endoscopic ultrasonography, and intraductal ultrasonography. *Eur J Radiol* 2001; **38**: 94-104
27 **Ueno N**, Tomiyama T, Tano S, Wada S, Miyata T. Color Doppler ultrasonography in the diagnosis of portal vein invasion in patients with pancreatic cancer. *J Ultrasound Med* 1997; **16**: 825-830
28 **Numata K**, Ozawa Y, Kobayashi N, Kubota T, Shimada H, Nozawa A, Nakatani Y, Sugimori K, Matsuo K, Imada T, Tanaka K. Contrast-enhanced sonography of pancreatic carcinoma: correlations with pathological findings. *J Gastroenterol* 2005; **40**: 631-640
29 **Fischer L**, Kleeff J, Esposito I, Hinz U, Zimmermann A, Friess H, Büchler MW. Clinical outcome and long-term survival in 118 consecutive patients with neuroendocrine tumours of the pancreas. *Br J Surg* 2008; **95**: 627-635
30 **Dixon E**, Pasieka JL. Functioning and nonfunctioning neuroendocrine tumors of the pancreas. *Curr Opin Oncol* 2007; **19**: 30-35
31 **Procacci C**, Carbognin G, Accordini S, Biasiutti C, Bicego E, Romano L, Guarise A, Minniti S, Pagnotta N, Falconi M. Nonfunctioning endocrine tumors of the pancreas: possibilities of spiral CT characterization. *Eur Radiol* 2001; **11**: 1175-1183
32 **Minniti S**, Bruno C, Biasiutti C, Tonel D, Falzone A, Falconi M, Procacci C. Sonography versus helical CT in identification and staging of pancreatic ductal adenocarcinoma. *J Clin Ultrasound* 2003; **31**: 175-182
33 **Solbiati L**, Tonolini M, Cova L, Goldberg SN. The role of contrast-enhanced ultrasound in the detection of focal liver leasions. *Eur Radiol* 2001; **11** Suppl 3: E15-E26
34 **D'Onofrio M**, Mansueto G, Vasori S, Falconi M, Procacci C. Contrast-enhanced ultrasonographic detection of small pancreatic insulinoma. *J Ultrasound Med* 2003; **22**: 413-417
35 **Flath B**, Rickes S, Schweigert M, Lochs H, Possinger K, Wermke W. Differentiation of a pancreatic metastasis of a renal cell carcinoma from a primary pancreatic carcinoma by echo-enhanced power Doppler sonography. *Pancreatology* 2003; **3**: 349-351
36 **Megibow AJ**. Secondary pancreatic tumors: imaging. In: Procacci C, Megibow A, editors. Imaging of the pancreas: cystic and rare tumors. Berlin: Springer-Verlag, 2003: 277-288
37 **Compagno J**, Oertel JE. Microcystic adenomas of the pancreas (glycogen-rich cystadenomas): a clinicopathologic

study of 34 cases. *Am J Clin Pathol* 1978; **69**: 289-298
38 **Procacci C**, Biasiutti C, Carbognin G, Accordini S, Bicego E, Guarise A, Spoto E, Andreis IA, De Marco R, Megibow AJ. Characterization of cystic tumors of the pancreas: CT accuracy. *J Comput Assist Tomogr* 1999; **23**: 906-912
39 **Procacci C**, Carbognin G, Biasiutti C, Ghilardi C, Misiani G, Schenal G, Tapparelli M. [Serous cystadenoma of the pancreas: imaging findings] *Radiol Med* 2001; **102**: 23-31
40 **Khurana B**, Mortelé KJ, Glickman J, Silverman SG, Ros PR. Macrocystic serous adenoma of the pancreas: radiologic-pathologic correlation. *AJR Am J Roentgenol* 2003; **181**: 119-123
41 **Procacci C**, Graziani R, Bicego E, Bergamo-Andreis IA, Mainardi P, Zamboni G, Pederzoli P, Cavallini G, Valdo M, Pistolesi GF. Intraductal mucin-producing tumors of the pancreas: imaging findings. *Radiology* 1996; **198**: 249-257
42 **Hammond N**, Miller FH, Sica GT, Gore RM. Imaging of cystic diseases of the pancreas. *Radiol Clin North Am* 2002; **40**: 1243-1262
43 **Cohen-Scali F**, Vilgrain V, Brancatelli G, Hammel P, Vullierme MP, Sauvanet A, Menu Y. Discrimination of unilocular macrocystic serous cystadenoma from pancreatic pseudocyst and mucinous cystadenoma with CT: initial observations. *Radiology* 2003; **228**: 727-733
44 **Buetow PC**, Rao P, Thompson LD. From the Archives of the AFIP. Mucinous cystic neoplasms of the pancreas: radiologic-pathologic correlation. *Radiographics* 1998; **18**: 433-449
45 **Fugazzola C**, Procacci C, Bergamo Andreis IA, Iacono C, Portuese A, Dompieri P, Laveneziana S, Zampieri PG, Jannucci A, Serio G. Cystic tumors of the pancreas: evaluation by ultrasonography and computed tomography. *Gastrointest Radiol* 1991; **16**: 53-61
46 **D'Onofrio M**, Caffarri S, Zamboni G, Falconi M, Mansueto G. Contrast-enhanced ultrasonography in the characterization of pancreatic mucinous cystadenoma. *J Ultrasound Med* 2004; **23**: 1125-1129
47 **Procacci C**, Megibow AJ, Carbognin G, Guarise A, Spoto E, Biasiutti C, Pistolesi GF. Intraductal papillary mucinous tumor of the pancreas: a pictorial essay. *Radiographics* 1999; **19**: 1447-1463
48 **Procacci C**, Carbognin G, Biasiutti C, Guarise A, Ghirardi C, Schenal G. Intraductal papillary mucinous tumors of the pancreas: spectrum of CT and MR findings with pathologic correlation. *Eur Radiol* 2001; **11**: 1939-1951
49 **Zamboni G**, Capelli P, Pesci A, Brighenti A. Pathology of cystic tumor. In: Procacci C, Megibow A, editors. Imaging of the pancreas: cystic and rare tumors. Berlin: Springer-Verlag, 2003: 85-94
50 **Lewin M**, Hoeffel C, Azizi L, Lacombe C, Monnier-Cholley L, Raynal M, Arrivé L, Tubiana JM. [Imaging of incidental cystic lesions of the pancreas] *J Radiol* 2008; **89**: 197-207
51 **Fukukura Y**, Fujiyoshi F, Sasaki M, Inoue H, Yonezawa S, Nakajo M. Intraductal papillary mucinous tumors of the pancreas: thin-section helical CT findings. AJR *Am J Roentgenol* 2000; **174**: 441-447
52 **Sahani DV**, Kadavigere R, Blake M, Fernandez-Del Castillo C, Lauwers GY, Hahn PF. Intraductal papillary mucinous neoplasm of pancreas: multi-detector row CT with 2D curved reformations--correlation with MRCP. *Radiology* 2006; **238**: 560-569

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REVIEW

Recent advances in breast cancer radiotherapy: Evolution or revolution, or how to decrease cardiac toxicity?

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Abstract

Radiation therapy has a major role in the management of breast cancers. However, there is no consensus on how to irradiate and on volume definitions, and there are strong differences in strategies according to different centers and physicians. New treatment protocols and techniques have been used with the principal purpose of decreasing lung and heart toxicity and adapting radiation treatment to patients' anatomy. There is evidence that indicates internal mammary chain radiotherapy should be used carefully and that high quality techniques should be used for decreasing the dose delivered to the heart. This review of the literature presents the state of the art on breast cancer radiotherapy, with special focus on the indications, techniques, and potential toxicity.

Key words: Cardiac toxicity; Ejection fraction; Breast cancer; Radiotherapy; Chemotherapy; Herceptin

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INTRODUCTION

Adjuvant radiotherapy to the breast plays a significant role in preventing local failure in women with tumorectomy for early stage breast cancer, as well as postmastectomy chest wall irradiation. Following surgery for early breast cancer, breast irradiation decreases the rate of in-breast local recurrence significantly, which has been demonstrated by randomized trials[1]. Results of a meta analysis showed that there were more cardio related deaths in the group of irradiated patients compared with non irradiated patients[2,3], however, in this period old techniques and treatment modalities were used[2]. On the other hand, with new advances in tumor control and long term survival, breast cancer patients have enough time to develop long term complications[3,4]. In some cases, the principal cause of complications is the anti cancer treatment, in others, there is no direct relationship between heart disease and the use of chemotherapy, radiotherapy and/or targeted treatment. Cardiac toxicity represents a multifactorial process with extreme complexity and direct relationship with patients' anatomy, habits, co morbidities, and risk factors. Also, received treatment, such as anthracycline-based chemotherapy or capecitabine, radiation therapy, hormonal therapy, target treatments such as trastuzumab, can affect cardiac toxicity. Drug-related cardiac toxicity in patients treated with high-dose chemotherapy has been well described for some drugs[4-6]. For others, such as targeted treatment

with trastuzumab, studies are beginning[7-9]. The question is how to decrease radiation induced cardiac toxicity using modern techniques of radiotherapy and how we can elucidate predictive factors in some patients indicating they are at risk to develop this kind of toxicity.

BREAST IRRADIATION AFTER BREAST CONSERVING SURGERY

Breast conserving radiotherapy uses tangential fields. Any other beam incidence would lead to useless irradiation of the underlying lung and heart[10]. The possibilities and the limits of commonly used techniques for irradiation of breast with two tangential fields in supine position have been discussed in recent years[11-13]. The volume of irradiated lung, heart, and contralateral breast, must be considered. Treatment-related complications include cardiovascular morbidity that can translate into an increased risk of mortality in the long term[11] and chronic radiation-induced pneumonitis. The early and late complications of radiation are directly related to the patient's anatomy, total dose delivered, fractionation scheme, and radiation technique.

It can be difficult to understand and represent doses received by organs at risk (OAR) (Table 1). An example is given with the French recommendations, showing there is no clear explanation for which parts of the heart can withstand these doses, for example, coronary arteries or the muscle. Every type of treatment is associated with a different kind of toxicity, and more details are needed to report the doses received by different OAR. For example, concerning lung irradiation, there is a question whether suggested doses should be designated to patients with only breast irradiation or breast and lymph node area radiation.

According to some authors, large, pendulous breasts are, in some cases, a contraindication for breast conservation because cosmetic results have been unsatisfactory with increased fibrosis and retraction[12,13]. A number of institutions have reported the use of different techniques to improve the dose distribution within the breast, decrease acute toxicities, decrease the dose to normal tissues and improve the daily reproducibility of women with large breasts[14-21]. Two simple techniques have already been shown to be safe: breast irradiation in a prone position, which is a technique developed in MSCCC, New York, USA, and an isocentric lateral decubitus position founded in the Institute Curie, Paris, France[18-20]. These two techniques were created to prevent lung and heart irradiation. Example of left side breast cancer treated in a lateral decubitus position is given in Figure 1. This treatment is perfectly adapted for breast irradiation only in the elderly, in cases of patients with lung and/or heart co-morbidities, smokers, patients with pendulous breasts, patients treated with chemotherapy, and other specific cases[22]. The limit is that these two techniques are created and adapted to only breast irradiation.

For teams without facilities for using the previously described techniques, new developments are also available[21]. Wedges cannot compensate for the change in breast shape in the cranio-caudal direction. A field reduction is necessary at the breast fold to avoid overdosage and treatment complications in this area. Dose uniformity throughout the whole breast volume can be achieved by using MLC sub-fields that are shaped to the successive isodoses found in the dose distribution[23].

Table 1 Doses to organs at risk (OAR) according to recommendations of the French Society of Radiation Oncology

Lung	V20 < 15%, V30 < 10%
Heart	< 35 Gy
Liver	V30 < 50%
Spinal cord	< 45 Gy
Esophagus	Maximum 40 Gy in 15 cm
Larynx	< 20%
Thyroid	Must be protected
Brachial plexus	< 55 Gy

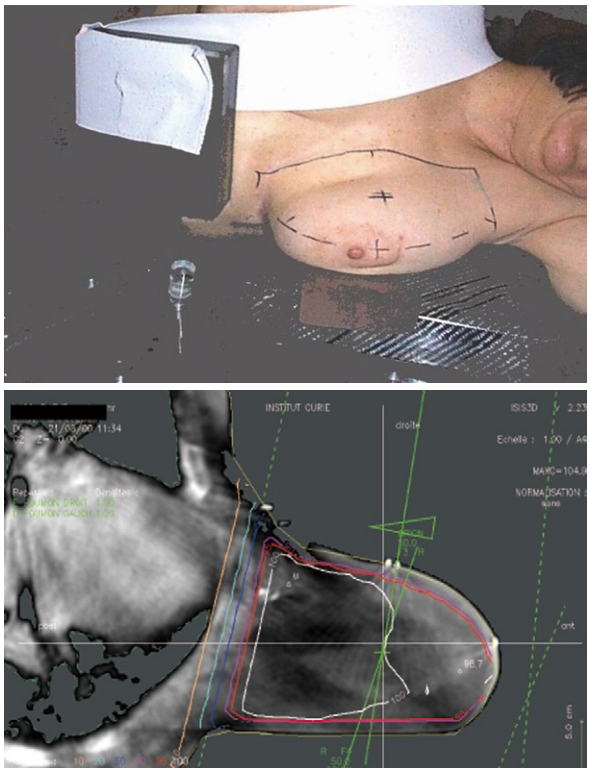

Figure 1 Patient's position and dosimetry of patient treated in a lateral position.

The definition of tumor bed "boost" volume is currently also well defined in numerous papers (Figure 2). New techniques such as pre- and post-operative CT scan image registration are used.

CHEST WALL IRRADIATION AFTER MASTECTOMY AND LYMPH NODE AREAS, INDICATIONS AND NEW TECHNIQUES OF IRRADIATION

The benefit of adjuvant radiotherapy to the chest wall

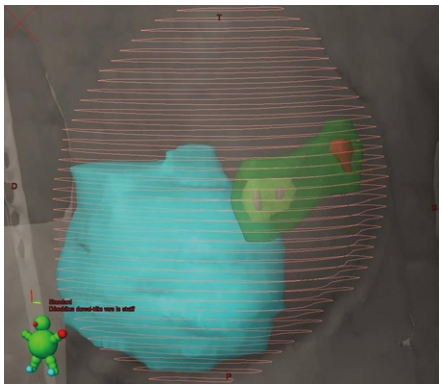

Figure 2 3D reconstruction of boost volume PTV (green) = GTV (red) + CTV clips (yellow), the breast delineation (pink lines) and the relationship between breast volume and boost volume with the cardiac structure[24].

has been controversial for many years. Published data have shown that radiotherapy regimens produced moderate but definite reductions, not only in breast cancer mortality, but also in overall mortality[1,25-29]. The benefit of postmastectomy radiotherapy, independently of the effects of systemic treatment, was shown also in studies of the Danish Breast Cancer Cooperative Group and the British Columbia study[25-31]. However, the first meta-analysis report did not find any advantage in overall survival over 10 and 20 years[2]. One explanation is the increase of non-breast cancer deaths, particularly cardiac disease in relation to older irradiation techniques[2].

Two opposed tangential photon beams is a common technique for postmastectomy radiotherapy to the chest wall[10]. Electron-beam radiotherapy of the chest wall is also used routinely[32-38]. It has been shown that this technique yielded similar loco-regional control, disease free survival and overall survival rates as standard photon beam irradiation[37]. Postmastectomy electron beam chest wall irradiation is well tolerated with low rates of early toxicity events. New developments could continue to improve the previously existing techniques with better dose distribution and decrease of the doses to lung and heart. This is a clinical step towards conformal electron therapy[38,39].

The importance of adjuvant treatment of regional lymph nodes (LN) in N-positive patients, especially with more than 3 involved axillary LN, has already been shown[1]. However, there is no consensus for the adjuvant treatment of internal mammary chain (IMC) and supra and infra clavicular LN, with strong differences in strategies according to centers and physicians. Indications for IMC radiotherapy are debated, since this treatment significantly increases the dose delivered to the heart and leads to potential technical difficulties. Although these data warrant confirmation by the EORTC prospective trial, there is evidence that the indications for IMC radiotherapy should be carefully considered and that high quality techniques should be used for decreasing the dose delivered to the heart. Previously published techniques using electron beams has already been shown to be safe[38].

Table 2 Simplified rules delineate the lymph node areas before conformal radiotherapy treatment

Supra clavicular region: contouring of the supraclavicular region is guided by the origin of the internal mammary artery
Cranial: Thyroid cartilage
Caudal: Clavicular head
Medial (med): Trachea
Posterior (post)-lateral (lat): Anterior scalene muscle
Post-med: Carotid artery
Infra clavicular region: The infraclavicular region corresponds to lymphatic drainage between axillary vertex and the superior limit of the axillary LN dissection (LND)
Cranial: Pectoralis minor
Caudal: Sternoclavicular joint
Lat: Pectoralis minor (medial side)
Med: Clavicle
Ant: Pectoralis major
Post: Axillary artery
Internal mammary chain: The lymph nodes of the IMC are located within the anterior interspaces; they are located either medially or laterally to the vessels and are concentrated in the upper three interspaces
Ant: Ant. part of the vascular area
Post: The pleura
Med: Medial limit of the vascular area
Lat: Lateral limit of the vascular area
Caudal: Superior side of the 4th rib
Cranial: Inferior limit of supra clavicular area
Rotter LN or intra pectoral node: situated between: pectoralis major and pectoralis minor at the 2nd intercostal space
Axilla
Ant: Pectoralis major & pectoralis minor
Post: Subscapularis, teres major and latissimus dorsi
Med: Seratus anterior
Lat: 5 mm backward the skin
Caudal: 4th and 5th ribs
Cranial: Inferior limit of infraclavicular volume or "first clip" after sentinel lymph node procedure

Another revolution in radiotherapy over the last few years is the development of less toxic techniques of irradiation of LN after careful delineation and adaption to the patients' anatomy[24,40-45] using high performing radiotherapy. Conformal radiotherapy requires definition of target volumes by anatomical limits based on delineation from CT images. Some authors have proposed anatomically based landmarks, specific for breast cancer radiotherapy, to delineate all regional LN[40-43]. Simplified rules of delineation have been developed in our department to delineate lymph node areas before conformal radiotherapy treatment, using easy to find anatomical structures (Table 2 and Figure 3).

CARDIAC TOXICITY RELATED TO CHEMOTHERAPY, TARGETED TREATMENTS, HORMONAL THERAPY

Other adjuvant treatments for breast cancer have been shown to be cardiotoxic. The principal chemotherapy in treatment of breast cancer is still anthracycline-based chemotherapy and the toxicity of this chemotherapy is well

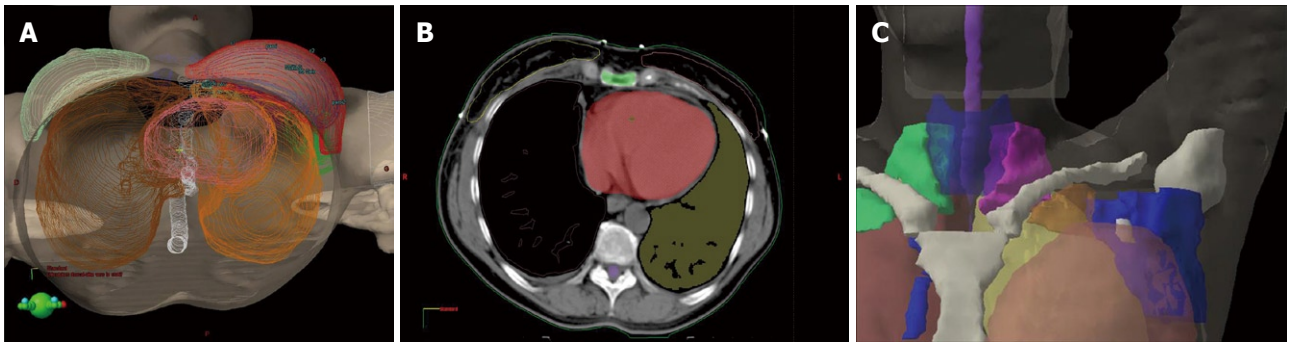

Figure 3 3D reconstruction of defined target volumes and the organs of risk. A: The left breast is shown in red, heart in pink, lungs in brown and yellow, thyroid in blue, spinal cord in white; B: Process of practical delineation of breast, lymph nodes and organs of risk; C: 3D reconstruction of defined target LN volumes (supra clavicular LN: fuschia, infra clavicular LN: ochre, axilla: dark blue, internal mammary chain: blue, Rotter LN, white) and thyroid (dark blue) as organ of risk.

known and documented[4-6]. The principal example comes from assessment of cardiac status in long-term survivors of pediatric malignancies who received chemotherapy, including anthracyclines. Steinherz *et al*[6] have studied 201 patients who had received a total anthracycline dose of 200 mg/m^2 to 1275 mg/m^2 (median, 450 mg/m^2), and 51 patients had mediastinal radiotherapy. The overall incidence and severity of abnormal systolic cardiac function were determined for the entire cohort. Risk factors of total anthracycline dose, mediastinal radiotherapy, age during treatment, and length of follow-up were examined. Twenty-three percent (47/201) of the cohort had abnormal cardiac function on noninvasive testing at long-term follow-up. Correlation between total cumulative dose, length of follow-up, and mediastinal irradiation with incidence of abnormalities was significant. Fifty-six patients were followed up for 10 years or more (median, 12 years), with a median anthracycline dose of 495 mg/m^2. Thirty-eight percent (21/56) of these patients, compared with 18% (26/145) of patients evaluated after less than 10 years, had abnormal findings. Sixty-three percent of patients followed up for 10 years or more after receiving 500 mg/m^2 or more of anthracyclines had abnormal findings. Nine of 201 patients had late symptoms, including cardiac failure and dysrhythmia, and three patients died suddenly. Microscopic examination of the myocardium on biopsy and autopsy revealed fibrosis. This study illustrates the importance of evaluation of all received treatments and not only one isolated treatment modality.

Other treatments, such as capecitabine, cyclophosphamide, trastuzumab, have also shown cardiac toxicity. Provided that the technique is adapted, the acute skin and heart toxicities of the concomitant administration of trastuzumab-RT appeared satisfactory[8].

PATIENTS' CO MORBIDITIES

Currently, patients at high risk for cardiac toxicity from usual chemotherapy are evaluated by an anesthesiologist before their surgical procedure and are also evaluated by their oncologist with test results from ejection fraction, electrocardiogram and anamnesis of history of cardiac disease.

There is a trend towards cardiac toxicity in patients with a past history of low ejection fraction, although seemingly poor cardiac risk patients may fare well with high doses of chemotherapy if carefully selected with the aid of a thorough cardiac evaluation with electrocardiogram and cardiac ultrasound. Currently, in our department, in the case of concomitant systemic treatment and radiotherapy, left ventricular ejection fractions, assessed at baseline, before start of RT, after completion of RT and then every 4-6 mo with either echocardiography or multiple gated acquisition scanning, were considered normal if $\geqslant$ 50% or stated so by the cardiologist.

At the same time, other risk factors, such as obesity, known cardiac and vascular dysfunction and smoking history must be evaluated.

CONCLUSION

Improvements in breast cancer radiotherapy in the last few years have been spectacular. This fact probably will result in decreasing the side effects of radiation treatment and will improve the quality of life of treated patients with lower rates of side effects. At the same time, the evaluation of long term side effects of new systemic treatments, such as chemotherapy, new targeted drugs, and hormonal treatments, is needed.

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REFERENCES

1 **Clarke M**, Collins R, Darby S, Davies C, Elphinstone P, Evans E, Godwin J, Gray R, Hicks C, James S, MacKinnon E, McGale P, McHugh T, Peto R, Taylor C, Wang Y. Effects of radiotherapy and of differences in the extent of surgery for early breast cancer on local recurrence and 15-year survival: an overview of the randomised trials. *Lancet* 2005; **366**: 2087-2106

2 **Darby S**. The Early Breast Cancer Trialists' Collaborative

Group (EBCTCG): Late complications of radiation therapy, ESTRO Course: Multidisciplinary management of breast cancer. Lisbon, 2009
3 **Darby SC**, McGale P, Taylor CW, Peto R. Long-term mortality from heart disease and lung cancer after radiotherapy for early breast cancer: prospective cohort study of about 300,000 women in US SEER cancer registries. *Lancet Oncol* 2005; **6**: 557-565
4 **Brockstein BE**, Smiley C, Al-Sadir J, Williams SF. Cardiac and pulmonary toxicity in patients undergoing high-dose chemotherapy for lymphoma and breast cancer: prognostic factors. *Bone Marrow Transplant* 2000; **25**: 885-894
5 **Gianni L**, Norton L, Wolmark N, Suter TM, Bonadonna G, Hortobagyi GN. Role of anthracyclines in the treatment of early breast cancer. *J Clin Oncol* 2009; **27**: 4798-4808
6 **Steinherz LJ**, Steinherz PG, Tan CT, Heller G, Murphy ML. Cardiac toxicity 4 to 20 years after completing anthracycline therapy. *JAMA* 1991; **266**: 1672-1677
7 **Alm El-Din MA**, Bellon JR, Strom EA, Bourgier C, Jagsi R, Niemierko A, Marsiglia H, Pierce L, Buchholz TA, Taghian AG. Radiation treatments may contribute to the development of cardiac dysfunction in breast cancer patients yreated with chemotherapy and trastuzumab. *Int J Radiat Oncol Biol Phys* 2008; **72**: S89-S90
8 **Kirova YM**, Caussa L, Granger B, Savignoni A, Dendale R, Campana F, Tournat H, Pierga JY, Fourquet A, Bollet MA. [Monocentric evaluation of the skin and cardiac toxicities of the concomitant administration of trastuzumab and radiotherapy] *Cancer Radiother* 2009; **13**: 276-280
9 **Bellon JR**, Gover MT, Burstein HJ, Harris JR, Harris LN. Concurrent trastuzumab and radiation therapy (RT) in the adjuvant treatment of breast cancer. *Int J Radiat Oncol Biol Phys* 2005; **63**: S55-S56
10 **Halperin EC**, Perez CA, Brady LW, Wazer DE. Principles and practice of radiation oncology. Lippincott Williams & Wilkins, 2008
11 **Krasin M**, McCall A, King S, Olson M, Emami B. Evaluation of a standard breast tangent technique: a dose-volume analysis of tangential irradiation using three-dimensional tools. *Int J Radiat Oncol Biol Phys* 2000; **47**: 327-333
12 **Leonardi MC**, Brambilla MG, Zurrida S, Intra M, Frasson A, Severi G, Robertson C, Orecchia R. Analysis of irradiated lung and heart volumes using virtual simulation in postoperative treatment of stage I breast carcinoma. *Tumori* 2003; **89**: 60-67
13 **Lu XQ**, Sullivan S, Eggleston T, Holupka E, Bellerive M, Abner A, Lamb CC, Lee A, Stevenson MA, Recht A. A three-field breast treatment technique with precise geometric matching using multileaf collimator-equipped linear accelerators. *Int J Radiat Oncol Biol Phys* 2003; **55**: 1420-1431
14 **Harris JR**, Levene MB, Svensson G, Hellman S. Analysis of cosmetic results following primary radiation therapy for stages I and II carcinoma of the breast. *Int J Radiat Oncol Biol Phys* 1979; **5**: 257-261
15 **Prosnitz LR**, Goldenberg IS, Harris JR, Hellman S, Danoff BF, Kramer S, Wallner PE, Brady LW. Radiotherapy for carcinoma of the breast instead of mastectomy. An update. *Front Radiat Ther Oncol* 1983; **17**: 69-75
16 **Cross MA**, Elson HR, Aron BS. Breast conservation radiation therapy technique for women with large breasts. *Int J Radiat Oncol Biol Phys* 1989; **17**: 199-203
17 **Mazonakis M**, Varveris H, Damilakis J, Theoharopoulos N, Gourtsoyiannis N. Radiation dose to conceptus resulting from tangential breast irradiation. *Int J Radiat Oncol Biol Phys* 2003; **55**: 386-391
18 **Grann A**, McCormick B, Chabner ES, Gollamudi SV, Schupak KD, Mychalczak BR, Heerdt AS, Merchant TE, Hunt MA. Prone breast radiotherapy in early-stage breast cancer: a preliminary analysis. *Int J Radiat Oncol Biol Phys* 2000; **47**: 319-325
19 **Merchant TE**, McCormick B. Prone position breast irradiation. *Int J Radiat Oncol Biol Phys* 1994; **30**: 197-203
20 **Campana F**, Kirova YM, Rosenwald JC, Dendale R, Vilcoq JR, Dreyfus H, Fourquet A. Breast radiotherapy in the lateral decubitus position: A technique to prevent lung and heart irradiation. *Int J Radiat Oncol Biol Phys* 2005; **61**: 1348-1354
21 **Fournier-Bidoz N**, Kirova Y, Campana F, El Barouky J, Zefkili S, Dendale R, Bollet MA, Mazal A, Fourquet A. Technique alternatives for breast radiation oncology: Conventional radiation therapy to tomotherapy. *J Med Phys* 2009; **34**: 149-152
22 **Bollet MA**, Campana F, Kirova YM, Dendale R, Saliou MG, Rosenwald JC, Fourquet A. Breast radiotherapy in women with pectus excavatum (funnel chest): is the lateral decubitus technique an answer? A dosimetric study. *Br J Radiol* 2006; **79**: 785-790
23 **Vicini FA**, Sharpe M, Kestin L, Martinez A, Mitchell CK, Wallace MF, Matter R, Wong J. Optimizing breast cancer treatment efficacy with intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys* 2002; **54**: 1336-1344
24 **Kirova YM**, Fournier-Bidoz N, Servois V, Laki F, Pollet GA, Salmon R, Thomas A, Dendale R, Bollet MA, Campana F, Fourquet A. How to boost the breast tumor bed? A multidisciplinary approach in eight steps. *Int J Radiat Oncol Biol Phys* 2008; **72**: 494-500
25 **Gebski V**, Lagleva M, Keech A, Simes J, Langlands AO. Survival effects of postmastectomy adjuvant radiation therapy using biologically equivalent doses: a clinical perspective. *J Natl Cancer Inst* 2006; **98**: 26-38
26 **Overgaard M**, Hansen PS, Overgaard J, Rose C, Andersson M, Bach F, Kjaer M, Gadeberg CC, Mouridsen HT, Jensen MB, Zedeler K. Postoperative radiotherapy in high-risk premenopausal women with breast cancer who receive adjuvant chemotherapy. Danish Breast Cancer Cooperative Group 82b Trial. *N Engl J Med* 1997; **337**: 949-955
27 **Overgaard M**, Jensen MB, Overgaard J, Hansen PS, Rose C, Andersson M, Kamby C, Kjaer M, Gadeberg CC, Rasmussen BB, Blichert-Toft M, Mouridsen HT. Postoperative radiotherapy in high-risk postmenopausal breast-cancer patients given adjuvant tamoxifen: Danish Breast Cancer Cooperative Group DBCG 82c randomised trial. *Lancet* 1999; **353**: 1641-1648
28 **Ragaz J**, Jackson SM, Le N, Plenderleith IH, Spinelli JJ, Basco VE, Wilson KS, Knowling MA, Coppin CM, Paradis M, Coldman AJ, Olivotto IA. Adjuvant radiotherapy and chemotherapy in node-positive premenopausal women with breast cancer. *N Engl J Med* 1997; **337**: 956-962
29 **Cuzick J**, Stewart H, Rutqvist L, Houghton J, Edwards R, Redmond C, Peto R, Baum M, Fisher B, Host H. Cause-specific mortality in long-term survivors of breast cancer who participated in trials of radiotherapy. *J Clin Oncol* 1994; **12**: 447-453
30 **Pierce LJ**. The use of radiotherapy after mastectomy: a review of the literature. *J Clin Oncol* 2005; **23**: 1706-1717
31 **Recht A**, Edge SB, Solin LJ, Robinson DS, Estabrook A, Fine RE, Fleming GF, Formenti S, Hudis C, Kirshner JJ, Krause DA, Kuske RR, Langer AS, Sledge GW Jr, Whelan TJ, Pfister DG. Postmastectomy radiotherapy: clinical practice guidelines of the American Society of Clinical Oncology. *J Clin Oncol* 2001; **19**: 1539-1569
32 **Gaffney DK**, Prows J, Leavitt DD, Egger MJ, Morgan JG, Stewart JR. Electron arc irradiation of the postmastectomy chest wall: clinical results. *Radiother Oncol* 1997; **42**: 17-24
33 **Gaffney DK**, Leavitt DD, Tsodikov A, Smith L, Watson G, Patton G, Gibbs FA, Stewart JR. Electron arc irradiation of the postmastectomy chest wall with CT treatment planning: 20-year experience. *Int J Radiat Oncol Biol Phys* 2001; **51**: 994-1001
34 **Magee B**, Ribeiro GG, Williams P, Swindell R. Use of an electron beam for post-mastectomy radiotherapy: 5-year

follow-up of 500 cases. *Clin Oncol* (R Coll Radiol) 1991; **3**: 310-314
35 **Hehr T**, Budach W, Paulsen F, Gromoll C, Christ G, Bamberg M. Evaluation of predictive factors for local tumour control after electron-beam-rotation irradiation of the chest wall in locally advanced breast cancer. *Radiother Oncol* 1999; **50**: 283-289
36 **Feigenberg SJ**, Price Mendenhall N, Benda RK, Morris CG. Postmastectomy radiotherapy: patterns of recurrence and long-term disease control using electrons. *Int J Radiat Oncol Biol Phys* 2003; **56**: 716-725
37 **Gez E**, Assaf N, Bar-Deroma R, Rosenblatt E, Kuten A. Postmastectomy electron-beam chest-wall irradiation in women with breast cancer. *Int J Radiat Oncol Biol Phys* 2004; **60**: 1190-1194
38 **Kirova YM**, Campana F, Fournier-Bidoz N, Stilhart A, Dendale R, Bollet MA, Fourquet A. Postmastectomy electron beam chest wall irradiation in women with breast cancer: a clinical step toward conformal electron therapy. *Int J Radiat Oncol Biol Phys* 2007; **69**: 1139-1144
39 **Campana F**, Kirova YM, Zervoudis S, Assi H, Fournier-Bidoz N, Dendale R, Iatrakis G, Bollet M, Kvrgins G, Peitsidis P, Fourquet A. Postmastectomy electron-beam chest wall irradiation in women with breast cancer: early and late complications. *Gyneco Ro* 2007; **3**: 170-173
40 **Kirova YM**, Castro Pena P, Dendale R, Servois V, Bollet MA, Fournier-Bidoz N, Campana F, Fourquet A. Simplified rules for everyday delineation of lymph node areas for breast cancer radiotherapy. *Br J Radiol* 2009; Epub ahead of print
41 **Kirova YM**, Castro Pena P, Dendale R, Campana F, Bollet MA, Fournier-Bidoz N, Fourquet A. [Definition of nodal volumes in breast cancer treatment and segmentation guidelines] *J Radiol* 2009; **90**: 747-751
42 **Kirova YM**, Servois V, Campana F, Dendale R, Bollet MA, Laki F, Fournier-Bidoz N, Fourquet A. CT-scan based localization of the internal mammary chain and supra clavicular nodes for breast cancer radiation therapy planning. *Radiother Oncol* 2006; **79**: 310-315
43 **Madu CN**, Quint DJ, Normolle DP, Marsh RB, Wang EY, Pierce LJ. Definition of the supraclavicular and infraclavicular nodes: implications for three-dimensional CT-based conformal radiation therapy. *Radiology* 2001; **221**: 333-339
44 **Martinez-Monge R**, Fernandes PS, Gupta N, Gahbauer R. Cross-sectional nodal atlas: a tool for the definition of clinical target volumes in three-dimensional radiation therapy planning. *Radiology* 1999; **211**: 815-828
45 **Castro Pena P**, Kirova YM, Campana F, Dendale R, Bollet MA, Fournier-Bidoz N, Fourquet A. Anatomical, clinical and radiological delineation of target volumes in breast cancer radiotherapy planning: individual variability, questions and answers. *Br J Radiol* 2009; **82**: 595-599

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BRIEF ARTICLE

Treatment of large lumbar disc herniation with percutaneous ozone injection *via* the posterior-lateral route and inner margin of the facet joint

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Abstract

AIM: To evaluate the effects of percutaneous ozone injection *via* the posterior-lateral route and inner margin of the facet joint in the treatment of large lumbar disc herniation.

METHODS: Fifty-eight patients with large lumbar disc herniation were treated with percutaneous injection of ozone *via* the posterior-lateral route and inner margin of the facet joint under digital subtraction angiography. Second injections were performed 5 d after the initial injection. All patients were followed up for 6-18 mo. A modified Macnab method was used for assessing clinical outcomes after oxygen-ozone therapy.

RESULTS: Successful puncture was obtained in all patients. The overall efficacy was 91.4%; the outcome was the excellent in 37 cases (63.8%), good in 16 cases (27.6%) and fair/poor in 5 cases (8.6%) according to the Macnab criteria. No severe complications were found throughout this study.

CONCLUSION: Percutaneous intradiscal ozone injection *via* the posterior-lateral route and inner margin of the facet joint is effective and safe for treatment of large lumbar disc herniation.

Key words: Lumbar vertebrae; Herniated disc; Facet joint; Zygapophysial joint; Ozone

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INTRODUCTION

In 2000, the Interventional Department of Nanfang Hospital, Southern Medical University, China was the first in our country to perform ozone therapy for lumbar disc herniation, and obtained good efficacy[1,2]. Because there is little pain, few complications and broad indications as well as being a minimally invasive method, ozone therapy has been widely used clinically before now[3,4]. At present, intradiscal and paravertebral injections through the posterior-lateral route are conventionally used in the treatment of lumbar disc herniation. For patients with minimal or inclusive disc herniation, the efficacy of ozone treatment is very significant, but for patients with large lumbar disc herniation, the efficacy is poor[5]. Since 2005, we have injected ozone *via* a route through both the posterior-lateral

pathway and inner margin of the facet joint in the treatment of 58 patients with large lumbar disc herniation, and we obtained good efficacy.

MATERIALS AND METHODS

Clinical materials

From January 2005 to December 2007, 58 patients with large lumbar disc herniation were enrolled in this study. A large lumbar disc hernia was where the greatest distance between the edges of the herniated material and the edges of the base of disc were more than 5 cm. Inclusion criteria were as follows: (1) diagnosis of a herniated disc by clinical symptoms, and physical signs matched with computed tomography (CT) and/or magnetic resonance imaging; (2) sciatic pain of 5 or more on a visual analogue scale; and (3) pain radiating to an area appropriate to a herniated disc. There were 43 and 15 females, aged from 22 to 78 years (mean, 40 years). Fifty-eight patients had 69 disc herniations. The positions of the herniated disc levels were L4-L5 (n = 31), L5-S1 (n = 16) and L4-L5 combined with L5-S1 (n = 11). The disease duration ranged from 1 mo to 12 years. The disc herniation portions ranged from 5 to 8 mm, with a mean of 5.87 ± 1.72 mm.

Four patients had disc protrusion and the protruding nucleus pulposus tilted to the lower extremity; the herniated discs of 3 patients were significantly calcified, with combined bony spinal canal stenosis at the same level as the herniated discs. Patients with the following were excluded: bony spinal canal stenosis, ligamentum flavum hypertrophy, and facet joint syndrome. The main clinical manifestations were radiating pain and numbness of the unilateral or bilateral hip and lower extremity, sometimes accompanied by low back pain and sacral pain. Only one case showed interruption of urinary and fecal excretion. As for physical signs, the straight leg raising test and/or strength test were positive in 51 cases, but both were negative in 7 cases. Thirteen cases showed muscular atrophy of the unilateral limb. Ten cases showed a reduction in the flexor muscle strength of the hallux combined with hyporeflexia of the knee and/or Achilles tendon. No beneficial effect had been achieved in any patient during at least 8 wk' conservative treatment.

Puncture through the posterior-lateral route

Ten milligrams diazepam was intramuscularly injected 30 min before the procedure. The patients lay in the lateral position on a digital subtraction angiography (DSA) operating table, with the affected side upwards. The operation was performed under sterile conditions. In general, the puncture site was 6-10 cm (mean, 8 cm) away from the vertebral line and 5 mL of 2% lidocaine (Xian Changcheng Pharmaceutical Factory, Xi'an, China) was used for local anesthesia of the puncture site, with attention paid to avoidance of damage to the nerve roots. The 21G needle (conical needlepoint and containing 3 side-holes) was used to puncture the center of the disc under DSA, with an angle of 30-40°, with insertion along the 'security triangle' through the posterior-lateral pathway. Once the position of the needle tip was confirmed in the center of the disc by both posterior-anterior and lateral fluoroscopy images, 5-10 mL of 30-40 μg/mL ozone was injected. The ozone generator used in our study was made by Humazon ProMedic, Germany. While the needle tip was withdrawn to near the intervertebral foramen, paravertebral injection of 10 mL ozone and 3-4 mL of an anti-inflammatory and analgesic solution (a mixture of diprospan (Schering_Plough, Shanghai, China), vitamin B12 (Hezhong Biochemistry Co. Ltd, Wuhan, China) and lidocaine) was performed. When the puncture site was at the level of L5-S1, a pillow was placed under the healthy hip and the lumbosacral angle was increased to shift the puncture point upwards, then the needle set at an angle of 150-160° to increase the success rate of puncture and injection of ozone along the margin of the disc.

Puncture through the inner margin of the facet joint

The patients lay in a prone position, and the angle of the plate of the DSA was adjusted so that its plane was perpendicular to the disc punctured, in order to show that the intervertebral space was clear, with the spinal process in the center. The puncture site was 2 cm away from the diseased spinal process in the intervertebral space and 5 mL of 2% lidocaine was injected for local infiltration anesthesia. Then a 20G needle was advanced stepwise into the hernia through the skin, subcutaneous tissue, and the space between the medial border of the articular process and the lateral border of the dural sac after the erector spinae. On meeting an obstacle, the angle of the needle was adjusted under lateral fluoroscopy to avoid the posterior margin of the vertebrae for entering the hernia, the ideal position of the needle tip being inside the herniated portion of the disc. When no blood or cerebrospinal fluid were drawn through the needle, ozone gas (5-6 mL of 30-40 μg/mL) was then injected slowly.

After ozone injection, patients were required to lie on the bed for 48 h. Later, limited activity was allowed but the duration of sitting or standing was not more than 15 min. The patients were administrated with mannitol and neurotropin for 3 d. Five days later, the treatment above was repeated. All patients were followed up by returning to the hospital to have physical examination or answering the questions by telephone. The efficacy was assessed by modified Macnab criteria[6,7]: excellent referred to return to work, but with occasional low back pain or leg pain, no need for painkillers and no physical signs of nerve root injury, and good physical fitness; good/fair referred to general ability to work, with intermittent slight low back pain or radiating pain, no need for painkillers and no physical signs of nerve root injury, and good physical fitness; poor referred to inability to work, with constant pain, requirement for painkillers, and limited physical activity, with physical signs of nerve root injury. The effective rate of the ozone therapy was assessed. The χ^2 test was used to evaluate the significant difference in efficacy among the 3 sub-groups (L4-L5 group, L5-S1 group and L4-L5 combined with L5-S1 group).

RESULTS

All 58 patients with 69 hernias had successful puncture

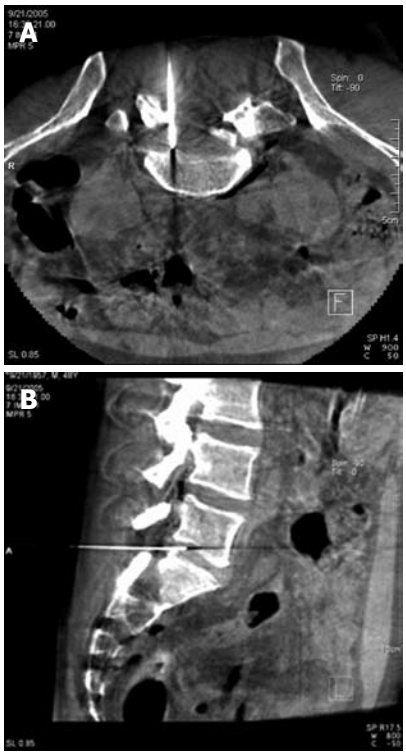

Figure 1 The placement of the needle tip measured accurately by Dyna-CT reconstruction under rotary digital subtraction angiography (DSA). A: The needle advanced into the disc through the inner margin of the facet joint and the needle tip was placed in the hernia under Dyna-CT cross-sectional reconstruction; B: The needle tip advanced into the disc through the posterior-lateral route under Dyna-CT sagittal reconstruction.

via the 2 paths, a success rate of 100%. The placement of the needle tip could be measured accurately by Dyna-CT reconstruction under rotary DSA (Figure 1A and B). After injection, all patients were followed up for 6 to 18 mo (mean, 10.5 ± 4.3 mo). According to the modified Macnab criteria, the therapeutic outcomes (Table 1) were: excellent efficacy in 37 cases (63.8%), good/fair in 16 (27.6%) and poor in 5 (8.6%), and the total effective rate (excellent and good/fair) was 91.4%. The total effective rate was 96.8% for L4-L5, 87.5% for L5-S1, and 81.8% for L4-L5 combined with L5-S1. According to statistical analysis, there was no significant difference among the 3 groups of patients with disc herniation at different levels ($\chi^2 = 4.407$, $P = 0.354$). In this study, there were no complications such as disc infection, nerve or vascular injury, and so on.

DISCUSSION

The treatment of lumbar disc herniation with ozone has been widely applied in our country, and at present, the main mechanism of action may be considered as follows[8,9]: (1) Immediate oxidation: ozone is a strong oxidizer, by which proteoglycan in the nucleus pulposus could be oxidized immediately, the osmotic pressure reduced and water lost. Then, the nucleus pulposus would denaturize, necrotize and atrophy, and the volume decrease. At the time of osmotic pressure reduction, the local blood circulation would also be changed. Increasing the oxygen supply could improve the symptoms; (2)

Table 1 Clinical outcome of 58 patients with lumbar disc herniation after ozone treatment according to modified Macnab's criteria *n* (%)

Herniated disc (case)	Macnab evaluation		
	Excellent	Good	Poor
L4-L5 (n = 31)	23 (74.2)	7 (22.6)	1 (3.2)
L5-S1 (n = 16)	9 (56.3)	5 (31.3)	2 (12.5)
L4-L5 and L5-S1 (n = 11)	5 (45.5)	4 (36.4)	2 (18.2)
Total	37 (63.8)	16 (27.6)	5 (8.6)

$\chi^2 = 4.407$, $P = 0.354$.

Anti-inflammatory effect: as the nerve root and the vein and lymphoid tissue were compressed by the herniated nucleus pulposus and annulus fibrosus, the venous and lymphatic backflow was obstructed, accompanied by nerve edema and exudation. Then antigenic substances, such as glycoprotein and β-lipoprotein, could be released to induce an immune response, resulting in aseptic inflammation, adhesion, *etc*. All these factors could lead to the pain of disc herniation. Ozone could have an anti-inflammatory effect by releasing antagonistic immune factors; and (3) Analgesic effect: the reason that the disc herniation caused pain was that some inflammatory mediators and enzyme-products (substance P, phospholipase A2, *etc*.) stimulated the nerve endings on the disc surface and near ligament, the facet articular process and lumbar muscle. The strong oxidative activity of ozone could inactivate the above inflammatory mediators for pain relief.

For small- or medium-sized disc herniations and contained disc herniations, which showed that the annulus fibrosus and posterior longitudinal ligament had not has not been completely ruptured, ozone injected into the center of disc through the conventional posterior-lateral route had good efficacy. In 2003, Andreula reported a multicenter study of a large group of patients (300 cases), with excellent and good outcomes of 78.3%[10]. However, for large disc herniation, ozone could not directly remove the hernia compressing the nerve root so that the symptoms could not be eliminated quickly and the efficacy of reduced compression was limited[11]. In another aspect, because the annulus fibrosus was partially or completely ruptured, the ozone injected could diffuse through the tear into the tissues surrounding the spinal or vertebral disc, such that the nucleus pulposus and hernia could not be fully oxidized[12]. Ozone injected through the inner margin of the facet joint by directly placing the needle into the herniated disc could directly oxidize the hernia, thus the efficacy was increased. At the same time, ozone diffusing between the dura mater and hernia could relieve nerve root pain.

This study showed that the treatment of large lumbar disc herniation with percutaneous ozone injection *via* the posterior-lateral and inner margin of facet joint was very effective. Also, the efficacy was not significantly different among the 3 levels of herniation including L4-L5, L5-S1, and both L4-L5 and L5-S1. It was proven that the dual approach treatment had a reliable outcome. If the herniation was on the L5-S1 level, it might be difficult to puncture because of an excessively high iliac crest and hypertrophic

transverse process. Thus, the needle path of the inner margin of the facet joint could be used to prevent puncture failure as a result of poor needle placement. In this way, the needle was advanced into the hernia through the gap between the lateral nerve root and the inner margin of the facet joint. However, for central herniation, the needle could be advanced through the gap between the lateral position of the nerve root and the dural sac. Because the needle was very thin and the ozone was minimally invasive for nerve root treatment, the inner margin of the facet joint approach has been a common path for minimally invasive treatment of disc herniation. Zhao[12] had performed this treatment with ozone and collagenase, with an effective rate of 94.4%. Because puncture through the inner margin of the facet joint had a straight path, a short distance, was an easy operation, and could allow 'target' injection, the efficacy was always good, especially for those patients with large disc herniation or prolapse. Ozone injection into or around the hernias not only improved the local ablation, but also eliminated local aseptic inflammation. The author had reported an excellent and good rate of 91.4%, which was higher than that of the route of the posterior-lateral approach only as reported by Yu *et al*[13], and that of the inner margin of the facet joint only as reported by Zhao[12]. Thus, the treatment of large lumbar disc herniation with percutaneous ozone injection *via* the posterior-lateral and inner margin of facet joint was a safe and effective method, which is worthy further promotion.

To ensure efficacy, the concentration of ozone should be adequate and the rupture of the annulus fibrosus by extremely high intradiscal pressure should be avoided. At present, there is pulse injection, low-pressure repeated injection and rapid injection with a large dose of ozone. The authors believed that, for large disc herniation, low-pressure repeat injections of ozone were preferable. By pushing and pulling the syringe repeatedly, the ozone could completely contact and oxidize the nucleus pulposus. Then the residual ozone was abandoned, and new ozone was injected repeatedly to avoid rupture of the annulus fibrosus. At the same time, the injection pressure should also be monitored by a pressure monitoring device to avoid the rupture of the annulus fibrosus.

COMMENTS

Background

Oxygen-ozone therapy is a minimally invasive treatment for lumbar disc herniation that exploits the biochemical properties of a gas mixture of oxygen and ozone. Oxygen-ozone therapy is a useful treatment for lumbar disc herniation that has failed to respond to conservative management.

Research frontiers

Although intradiscal and paravertebral ozone injections through the posterior-lateral route are effective in the treatment of lumbar disc herniation, the efficacy is poor for patients with large lumbar disc herniation. We report injection of ozone *via* both the posterior-lateral route and the inner margin of the facet joint to successfully treat large lumbar disc herniation.

Innovations and breakthroughs

This study showed that the treatment of large lumbar disc herniation with percutaneous ozone injection *via* the posterior-lateral route and inner margin of the facet joint was very effective. Ozone injected *via* the inner margin of the facet joint, by direct placement of the needle into the herniated disc, could directly oxidize the hernia. Because of its high penetration, the efficacy was increased. The efficacy was similar for the 3 levels of herniation including L4-L5, L5-S1, and both L4-L5 and L5-S1. It was proved that the dual approach to treatment had a reliable effect.

Applications

Large lumbar disc herniation had a poor response to ozone injection *via* the posterior-lateral route. Ozone injected through the inner margin of the facet joint could improve the efficacy. In our study, the overall efficacy was 91.4%, excellent in 37 cases (63.8%) and good in 16 cases (27.6%). The indication for ozone therapy has expanded to include large lumbar disc herniation.

Terminology

A zygapophysial joint (zygapophyseal, or facet joint) is a synovial joint between the superior articular process of one vertebra and the inferior articular process of the vertebra directly above it. There are 2 facet joints in each spinal motion segment. Large lumbar disc herniation is where the greatest distance between the edges of the herniated material and the edges of the base of disc are more than 5 cm. Dyna-CT is an innovative system for 3-dimensional reconstruction of anatomical structures.

Peer review

The manuscript is generally acceptable. However, some points must be reconsidered.

REFERENCES

1 **He XF**, Yu ZJ, Teng GJ, Li YH, Zeng QL, Chen Y, Lu W, Kong WD, Xu XL, Li L, Peng J. Treatment of lumbar disc herniation by using percutaneous intradiscal and paraspinal space injection of O2-O3 mixture. *Zhonghua Fangshexue Zazhi* 2003; **37**: 827-830

2 **Yu ZJ**, He XF, Chen Y, Zeng QL, Liu ZH, Zhao ZQ, Lu Y, Li YH. Percutaneous intradiscal ozone (O3)-injection: an experimental study in canines. *Zhonghua Fangshexue Zazhi* 2002; **36**: 366-369

3 **Hua SY**, Xu RL, Qi B. Clinical evaluation of lumbar disc heniation treated by percutaneous lumbar discectomy associated with O3 injection. *Jieru Fangshexue Zazhi* 2005; 14: 281-283

4 **Xiao YY**, Meng XD, Li JL, Chen C. CT guided O3 injection for the treatment of lumbar disc herniation. *Zhongguo Jieru Yingxiang Yu Zhiliaoxue* 2005; **2**: 245-248

5 **He XF**, Li YH, Chen HW, Lu W, Chen Y, Zeng QL, Zhao JB, Xu XL, Peng J, Shen P. Intradiscal injection of O2-O3 to treat lumbar disc herniations: clinical therapeutic effect analysis with 600 cases. *Zhongguo Jieru Yingxiang Yu Zhiliaoxue* 2005; **2**: 338-341

6 **Nerubay J**, Caspi I, Levinkopf M. Percutaneous carbon dioxide laser nucleolysis with 2- to 5-year followup. *Clin Orthop Relat Res* 1997; 45-48

7 **Macnab I**. Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty-eight patients. *J Bone Joint Surg Am* 1971; **53**: 891-903

8 **Muto M**, Andreula C, Leonardi M. Treatment of herniated lumbar disc by intradiscal and intraforaminal oxygen-ozone (O2-O3) injection. *J Neuroradiol* 2004; **31**: 183-189

9 **Arena M**, Savoca G, Papa R. Paravertebral percutaneous O2-O3 injection integrated treatments in the management of lunbar herniated disc and disc-joint compression. *Ital J Ozono Ther* 2003; **2**: 39-44

10 **Andreula CF**, Simonetti L, De Santis F, Agati R, Ricci R, Leonardi M. Minimally invasive oxygen-ozone therapy for lumbar disk herniation. *AJNR Am J Neuroradiol* 2003; **24**: 996-1000

11 **Wang DJ**, Zhang L, Wang XM, Xiao YY. Treatment of huge lumbar intervertebral disc herniation with ozone and collagenase through the route of inner margin of facet joint. *Shiyong Tengtongxue Zazhi* 2007; **3**: 22-27

12 **Zhao W**. Primary study on pressure-controlled lunbar intradiscal ozone injection with flexible puncture needle through inner margin of small joint. Master degree paper, First Military Medical University, 2007: 15

13 **Yu ZJ**, He XF, Li YH. Treatment of lumbar disc herniation with medical ozone. *Zhongguo Yixue Yingxiang Jishu* 2004; **20**: 598-600

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Meetings

Events Calendar 2010

January 4-8
Beaver Creek, Colorado, United States
18th Annual Winter Diagnostic Imaging Update

January 7-9
Leuven, Belgium
4th Leuven Course on Ear Imaging

January 16-17
Hollywood, Florida, United States
The Symposium on Clinical Interventional Oncology

January 17-21
Hollywood, Florida, United States
The International Symposium on Endovascular Therapy

January 21-22
Cairo, Egypt
BGICC Breast Gyne International Cancer Conference

January 21-24
Phoenix, AZ, United States
13th Society for Cardiovascular Magnetic Resonance (SCMR) Annual Scientific Sessions

January 23-23
Atlanta, GA, United States
Emory Winship Cancer Institute: Breast Cancer 2010: Advances in Science, Emerging Data, and Novel Therapeutics

January 25-29
Maui, HI, United States
Musculoskeletal & Neuroradiology MR Imaging Update in Maui

January 27-February 2
Albuquerque, NM, United States
2010 SNM Conjoint Mid-Winter Meetings

January 29-30
Barcelona, Spain
7th European Congress: Perspectives in Gynecologic Oncology

February 7-12
Vail, CO, United States
15th Annual Vail 2010: Multislice CT in Clinical Practice

February 11-13
Las Vegas, NV, United States
5th Annual Symposium on PET/CT and Molecular Imaging

February 16-19
Park City, UT, United States
6th Interventional/ Neurointerventional Conference

February 18-19
London, United Kingdom
Diagnostic and Interventional Radiology

February 18-21
Las Vegas, NV, United States
American Society of Spine Radiology Annual Symposium

February 20-20
Jacksonville, Florida, United States
Mayo Clinic Molecular Markers and Management of Breast Cancer

February 20-21
Bethesda, Maryland, United States
25th Anniversary Washington Neuroradiology Review

February 21-26
Orlando, FL, United States
The Abdominal Radiology Course

February 21-27
Snowmass, CO, United States
16th Annual Snowmass 2010: Clinical Ultrasound

February 22-26
Bethesda, MD, United States
48th Annual Dr. Kenneth M. Earle Memorial Neuropathology Review

February 24-27
Lake Buena Vista, FL, United States
ACRO 2010 American College of Radiation Oncology Symposium: Clinical Radiation Oncology Challenges

February 25-27
Chandler, AZ, United States
Multidisciplinary Head and Neck Cancer Symposium

February 26-27
Brussels, Belgium
10èmes Mises au Point en Imagerie Ostéo-Articulaire

February 27-March 1
Cairo, Egypt
7th Gastroenterology Hepatology & Endoscopy Symposium

February 28-March 4
Scottsdale, AZ, United States
International Congress XXIII on Endovascular Interventions

February 28-March 5
Breckenridge, CO, United States
5th Annual Breckenridge 2010: Musculoskeletal MRI

March 3-6
Las Vegas, Nevada, United States
11th Annual Advances in Breast Imaging and Interventions

March 4-8
Vienna, Austria
European Congress of Radiology (ECR 2010) Annual Meeting

March 5-7
Mt Tremblant, QC, Canada
Neuroimaging and Head & Neck Radiology Update in Mt Tremblant

March 7-11
San Diego, CA, United States
SCBT-MR Masters in Body Imaging: "What's New, What's Hot, What You May Not Have Known"

March 10-13
San Antonio, Texas, United States
Clinical Osteoporosis 2010: An ISCD-NOF Symposium

March 11-13
Barcelona, Spain
EORTC Group Meeting: EORTC Radiation Oncology Group

March 11-13
Hannover, Germany
40. Kongress der Deutschen Gesellschaft für Endoskopie und Bildgebende Verfahren e.V.

March 13-18
Tampa, FL, United states
Society of interventional radiology 35th Annual Scientific Meeting

March 14-17
Park City, UT, United States
14th Annual Park City 2010: MRI in Clinical Practice

March 22-26
Beaver Creek, CO, United States
NYU Radiology Spring Skiing Symposium in Beaver Creek

March 22-26
Maui, HI, United States
18th Annual Spring Diagnostic Imaging Update

March 24-27
San Diego, California, United States
2010 American institute of ultrasound in Medicine Annual Convention Preliminary Program

March 24-27
Barcelona, Spain
7th European Breast Cancer Conference

April 8-12
Shanghai, China
The 26th International Congress of Radiology

September 8-12
Guangzhou, China
Chinese Society of Interventional Radiology, 2010 CSIR

November 28-December 03
Chicago, United States
Radiological Society of North America: 2010 Annual Meeting

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Instructions to authors

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Acknowledgments
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Chinese journal article (list all authors and include the PMID where applicable)

2 **Lin GZ**, Wang XZ, Wang P, Lin J, Yang FD. Immunologic effect of Jianpi Yishen decoction in treatment of Pixu-diarrhoea. *Shijie Huaren Xiaohua Zazhi* 1999; **7**: 285-287

In press

3 **Tian D**, Araki H, Stahl E, Bergelson J, Kreitman M. Signature of balancing selection in Arabidopsis. *Proc Natl Acad Sci USA* 2006; In press

Organization as author

4 **Diabetes Prevention Program Research Group**. Hypertension, insulin, and proinsulin in participants with impaired glucose tolerance. *Hypertension* 2002; **40**: 679-686 [PMID: 12411462 PMCID:2516377 DOI:10.1161/01.HYP.0000035706.28494.09]

Both personal authors and an organization as author

5 **Vallancien G**, Emberton M, Harving N, van Moorselaar RJ; Alf-One Study Group. Sexual dysfunction in 1, 274 European men suffering from lower urinary tract symptoms. *J Urol* 2003; **169**: 2257-2261 [PMID: 12771764 DOI:10.1097/01.ju.0000067940.76090.73]

No author given

6 21st century heart solution may have a sting in the tail. *BMJ* 2002; **325**: 184 [PMID: 12142303 DOI:10.1136/bmj.325.7357.184]

Volume with supplement

7 **Geraud G**, Spierings EL, Keywood C. Tolerability and safety of frovatriptan with short- and long-term use for treatment of migraine and in comparison with sumatriptan. *Headache* 2002; **42** Suppl 2: S93-99 [PMID: 12028325 DOI:10.1046/j.1526-4610.42.s2.7.x]

Issue with no volume

8 **Banit DM**, Kaufer H, Hartford JM. Intraoperative frozen section analysis in revision total joint arthroplasty. *Clin Orthop Relat Res* 2002; (**401**): 230-238 [PMID: 12151900 DOI:10.1097/00003086-200208000-00026]

No volume or issue

9 Outreach: Bringing HIV-positive individuals into care. *HRSA Careaction* 2002; 1-6 [PMID: 12154804]

Books

Personal author(s)

10 **Sherlock S**, Dooley J. Diseases of the liver and billiary system. 9th ed. Oxford: Blackwell Sci Pub, 1993: 258-296

Chapter in a book (list all authors)

11 **Lam SK**. Academic investigator's perspectives of medical treatment for peptic ulcer. In: Swabb EA, Azabo S. Ulcer disease: investigation and basis for therapy. New York: Marcel Dekker, 1991: 431-450

Author(s) and editor(s)

12 **Breedlove GK**, Schorfheide AM. Adolescent pregnancy. 2nd ed. Wieczorek RR, editor. White Plains (NY): March of Dimes Education Services, 2001: 20-34

Conference proceedings

13 **Harnden P**, Joffe JK, Jones WG, editors. Germ cell tumours V. Proceedings of the 5th Germ cell tumours Conference; 2001 Sep 13-15; Leeds, UK. New York: Springer, 2002: 30-56

Conference paper

14 **Christensen S**, Oppacher F. An analysis of Koza's computational effort statistic for genetic programming. In: Foster JA, Lutton E, Miller J, Ryan C, Tettamanzi AG, editors. Genetic programming. EuroGP 2002: Proceedings of the 5th European Conference on Genetic Programming; 2002 Apr 3-5; Kinsdale, Ireland. Berlin: Springer, 2002: 182-191

Electronic journal (list all authors)

15 Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis serial online, 1995-01-03, cited 1996-06-05; 1(1): 24 screens. Available from: URL: http//www.cdc.gov/ncidod/EID/eid.htm

Patent (list all authors)

16 **Pagedas AC**, inventor; Ancel Surgical R&D Inc., assignee. Flexible endoscopic grasping and cutting device and positioning tool assembly. United States patent US 20020103498. 2002 Aug 1

Statistical data

Write as mean ± SD or mean ± SE.

Statistical expression

Express *t* test as *t* (in italics), *F* test as *F* (in italics), chi square test as χ^2 (in Greek), related coefficient as *r* (in italics), degree of freedom as υ (in Greek), sample number as *n* (in italics), and probability as *P* (in italics).

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Italics

Quantities: *t* time or temperature, *c* concentration, *A* area, *l* length, *m* mass, *V* volume.

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