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Contents

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EDITORIAL

Digital subtraction angiography for the analysis of supraaortic vessels: What is its role nowadays?

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Abstract

For about 50 years, angiography represented the only imaging method for studying carotid arteries in order to detect the presence of pathological stenosis due to atherosclerotic plaque. Recently, thanks to the use of non-invasive methods, physicians are able to study and quantify the presence of carotid atherosclerosis *in vivo*. These procedures have enabled the introduction of new concepts: (1) the degree of carotid stenosis is approximate to the volume and extension of carotid plaque; and (2) a set of parameters, easily identifiable by computed tomography angiography, magnetic resonance angiogram and ultra-sound echo-color Doppler, are closely linked to the development of ischemic symptoms and can significantly increase the risk of stroke regardless of the degree of stenosis. In light of these findings, vulnerable plaques should be identified early, and the role of Digital Subtraction Angiography which is a purely technical luminal technique should be determined.

Key words: Carotid arteries; Computed tomography angiography; Digital Subtraction Angiography

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INTRODUCTION

The term atherosclerosis is derived from the Greek words “atheroma” and “sclerosis” which mean “mush” and “hardening”, respectively. These two words indicate the hardening of the vascular wall and lumen reduction of the same vessel. Atherosclerosis remains the commonest cause of death in the Western world. A degree of carotid artery narrowing has been reported in up to 75% of men and 62% of women aged 65 years[1]. The first study to identify an association between carotid artery lesions and the incidence of stroke is attributed to Savory, who in 1856[2] reported the case of a woman with cerebrovascular symptoms and where the autopsy examination revealed an occlusion of the distal tract of the left internal carotid artery associated with a bilateral obstruction of the subclavian artery. Since this first report many others have been described[3-5] providing evidence of a strong correlation between carotid pathology and cerebral symptoms. Currently, this pathology is the third leading cause of severe disability in the Western world causing 4.5 million deaths[6,7]. It has been demonstrated that the majority of cerebrovascular events appear be a consequence of emboli from an atherosclerotic plaque or, acute occlusion of the carotid artery, with distal propagation of the thrombus. Therefore, the identification and characterization of atherosclerotic disease affecting the carotid arteries is fundamental.

DIGITAL SUBTRACTION ANGIOGRAPHY OF CAROTID ARTERIES

The history of intra-arterial angiography is glorious and from the first study published in 1924 by Brooks[8], techniques have continuously improved and ultrasoft catheters, high-resolution biplane angiography equipment and Digital Subtraction Angiography (DSA) are currently used. DSA is an imaging technique used in interventional and diagnostic radiology that requires femoral artery puncture and intra-arterial injection of contrast medium, usually into the aortic arch or the common carotid artery. It is possible to obtain images of the carotid stenotic lumen with high spatial resolution and an estimation of low dynamics, such as slow and delayed blood flow.

DSA was previously considered the gold standard for the study of carotid artery pathology, because of its high spatial (50 μm) and temporal resolution (10 ms). This method allows us to obtain optimal definition of the opacified lumen, as well as plaque characteristics such as lumen irregularity or plaque ulcerations[9-11]. However, DSA has some limitations, it is invasive, expensive (compared to Computed Tomography and Magnetic Resonance), time expensive and requires a period of bed rest. It is important to underline that with current technological improvements (use of small catheter sizes) DSA can now be considered a minimally-invasive procedure and that the period of bed rest, with the use of a closure device, is limited. The main concern with DSA is the risk of neurological complications, however, this point is debated: in 1990 the risk of permanent neurological complications reached approximately 0.9% and transient neurological complications approximately 2%[12]. However, in the last few years the risk of neurological complications after DSA is low; Thiex *et al*[13] in a paper published in the American Journal of Neuroradiology in 2010, evaluated the safety of DSA provided by a dedicated neurointerventional team in a high-volume university hospital. They analyzed a cohort of 1715 patients from 2000 to 2008 and observed that no strokes or permanent neurologic deficits were seen in any of the 1715 patients undergoing diagnostic neuroangiography and only one patient experienced a transitory ischemic attack (TIA). This study demonstrated that within a high-volume neurointerventional practice, the risk of neurologic complications related to DSA can approach zero.

For about 50 years, angiography has represented the only imaging method for studying carotid arteries in order to detect the presence of pathological stenosis due to atherosclerotic plaque[14,15]. Conventional angiography was considered the most accurate technique for the diagnosis of carotid bifurcation stenosis and remains the standard against which other methods are compared.

Carotid endarterectomy (CEA) trials were undertaken during the 1980s up to the mid-1990s[16], and the benefit of CEA according to the degree of stenosis measured by angiography was graded. Nowadays, conventional angiography, always considered the gold standard imaging technique, plays a role only when there is no agreement between different imaging modalities or when endovascular treatment (carotid artery stenting) is needed. For these reasons, non-invasive and less risky carotid imaging techniques have gradually replaced intra-arterial angiography in the quantification of the degree of carotid stenosis.

STENOSIS DEGREE QUANTIFICATION

Three multi-centric randomized studies, North American Symptomatic Carotid Endarterectomy Trial (NASCET), European Carotid Surgery Trial (ECST) and Asymptomatic Carotid AtheroSclerosis Group (ACAS), provided cut-off values for stenosis degree indicating the possible benefits of CEA[17-19]. In particular, for those patients with symptomatic high-grade stenosis (70%-99%) after 5 years of follow-up, the pooled analysis of these three trials proved the benefits (70%-99% NASCET stenosis with a risk reduction of 16%, $P < 0.001$) of undergoing endarterectomy.

NASCET, ECST and ACAS proposed that when the only imaging technique available was DSA, the degree of stenosis was evaluated as the percentage reduction in the luminal diameter of the artery. Differences existed in the evaluation of stenosis degree between NASCET, ECST and CSI. With the NASCET criteria, the ratio between the lumen diameter at the stenosis and distal normal lumen diameter with no stenosis was calculated. With the ECST criteria, the ratio between the lumen diameter at the stenosis and the total carotid diameter (including the plaque) was calculated, whereas with the CSI-index criteria, the ratio between the lumen diameter at the stenosis and normal lumen of the proximal common carotid artery first multiplied by 1.2 was calculated. It was demonstrated by Saba *et al*[20] that the NASCET and ECST methods showed a strong correlation and that inter-observer and intra-observer agreement values were high for both NASCET and ECST.

The methodology for carotid stenosis quantification is widely debated because the NACET, ECTS and CSI-index are indirect ratio-percent methods. These trials imaged carotid arteries using conventional angiography, and methods of deriving ratio-percent were adopted because standardized stenosis measurements were not consistent with film (in conventional angiography) and because when used, digital angiography demonstrated different degrees of magnification and a lack of millimetre (mm) calibration.

With the introduction of MDCTA, thanks to its high spatial resolution (with an isotropic voxel of 0.5 mm), Bartlett *et al*[21-23] proposed a new direct mm-method in order to overcome the limitations of the classical percent-methods. It was demonstrated that the simple mm measurement of stenosis can reliably predict NASCET-type, ECST-type and CSI-type percent stenosis[24].

In an editorial by Forsting *et al*[25] published in Stroke 2003, the Editors suggested that, from a clinical point of view, DSA could be replaced by non-invasive methods for the quantification of carotid artery stenosis degree. However, in a meta-analysis published by the Lancet in 2006, Wardlaw *et al*[15] suggested caution because, even if non-

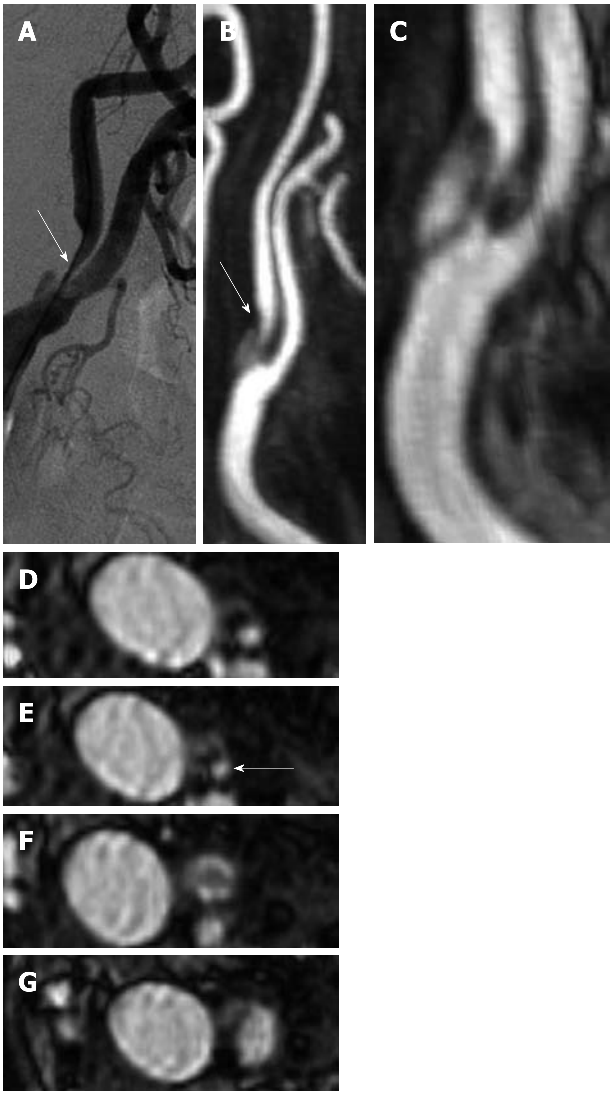

Figure 1 Digital Subtraction Angiography (A), CTA (B) and MRA (C-F) of the right carotid artery of a 74-year-old patient with right transitory ischemic attack. The blue arrows indicate the point of maximum stenosis degree.

invasive tests could probably replace DSA for 70%-99% of stenoses, insufficient data to determine their accuracy were provided, mostly in the presence of 50%-69% stenosis. These data have been confirmed in a paper recently published in Radiology by the same research group[26], where the authors stated that "Combinations of non-invasive tests do not improve both sensitivity and specificity but rather improve one at the expense of another".

On the basis of these data it is reasonable to assume that the measurement of carotid stenosis can be adequately performed with non-invasive techniques, bearing in mind that the diagnostic accuracy of DSA is still unsurpassed and represents the gold standard. Nevertheless, the relevance of and interest in imaging tests for carotid artery occlusive disease remains high. On the basis of data from randomized clinical trials, we know that accurate diagnosis of stenosis severity is critical for clinicians to sensibly recommend patients for subsequent intervention.

THE CAROTID ARTERY VULNERABLE PLAQUE

In the past few years, the degree of luminal stenosis has been used as a measure of atherosclerotic disease severity. Recent studies demonstrated that moderate carotid artery stenosis may lead to acute cerebral infarction and subsequent histopathology results showed that plaque erosion and disruption were common morphologic features found in symptomatic lesions indicating that *luminal narrowing* was not the sole predictor of cerebrovascular events[27-29].

These studies have enabled the introduction of new concepts: (1) the degree of carotid stenosis is approximate to the volume and extension of carotid plaque[30,31]; and (2) a set of parameters, easily identifiable by CTA, MRA and US-ECD, are closely linked to the development of ischemic symptoms and can significantly increase the risk of stroke regardless of the degree of stenosis[32,33].

At the same time, a greater understanding of the pathophysiology of cerebrovascular events has been reached and it is understood that stroke/TIA originating from the carotid arteries can be determined by the presence of elements of the plaque's embolization[34,35]. Another important parameter recently underlined in the literature is plaque volume. In fact, accumulation of atherosclerotic plaque in the carotid artery may lead to positive remodelling in which the artery enlarges to preserve the luminal area. In addition, a certain amount of atherosclerosis needs to be present in the carotid bulb before it causes stenosis. Some researchers have proposed that plaque volume is a better descriptor of the severity of atherosclerotic disease than the degree of stenosis[30]. Another interesting observation is that plaque composition changes with increasing plaque volume. According to the AHA criteria, which describe advanced atherosclerotic lesions in the carotid artery as containing more lipid and more calcium, an increase in the proportions of lipid and calcification were found with increasing plaque volume. Obviously, DSA does not provide information on plaque volume, because it is a purely "luminal" technique and for this type of analysis non-invasive techniques such as CTA, MRA or US are necessary.

CAROTID DIAGNOSTIC FLOW-CHART

The choice of a specific imaging modality to assess the carotid artery depends on several parameters and depends largely on the clinical indication for imaging and the skills available in individual centres. Recently, Jaff and colleagues[36] proposed a diagnostic algorithm for the correct use of imaging modalities according to the different clinical indication of the patients. In this paper published in 2008, it was proposed that for patients with a high likelihood of vascular disease, CTA may represent an appropriate first exam. On the other hand, for the screening of patients with a lower likelihood of neurovascular pathology, US-ECD should be selected. If significant stenotic disease of the ICA is detected, CTA as well as MRA (Figure 1) can be used to confirm the diagnosis and to accurately determine the precise degree of stenosis. DSA is necessary infrequently and only in cases of severe multiple vessel disease, for which assessment of flow direction and collateral patterns may be important or when the image quality of a non-invasive procedure is of limited value.

CONCLUSION

Gradually, we have evolved from the concept of risk arising from the degree of stenosis to the concept of vulnerable plaque[37]. Identification of high risk atherosclerotic plaque and quantification of biological markers, especially inflammation, have considerably boosted the prediction potential of vascular risk. As a result, we can assume that stenosis may be considered only one among several indirect signs of a plaque showing embolic risk.

In light of these findings, vulnerable plaques should be identified early, and the role of DSA which is a purely technical luminal technique should be determined.

DSA should not be regarded as a reference method in the assessment and risk stratification of the carotid artery. In fact, the degree of stenosis can be adequately assessed with non-invasive techniques allowing evaluation of all structural parameters of the plaque, which cannot be obtained with angiography.

New trials are now required, in order to incorporate the potential of new imaging techniques to determine which patients require treatment, whether medical, surgical or interventional. Moreover, non-invasive imaging techniques should help to gain further insight into the natural history of atherosclerotic carotid plaques[38].

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CASE REPORT

Small bowel perforation after duodenal stent migration: An interesting case of a rare complication

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Abstract

Duodenal stents are frequently used for palliating malignant gastric outlet obstruction. Successful stent placement relieves obstructive symptoms, is cost effective, and has a relatively low complication rate. However, enteral stents have the potential of migrating distally and rarely, even lead to bowel perforation. We present a rare case of a duodenal stent placed as a palliative measure for gastric outlet obstruction due to unresectable pancreatic cancer that migrated distally after a gastrojejunostomy resulting in small bowel perforation.

Key words: Small bowel perforation; Gastrojejunostomy; Stent migration; Duodenal stent; Pancreatic cancer; Gastric outlet obstruction

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Lee PHU, Moore R, Raizada A, Grotz R. Small bowel perforation after duodenal stent migration: An interesting case of a rare complication. *World J Radiol* 2011; 3(6): 152-154 Available from: URL: http://www.wjgnet.com/1949-8470/full/v3/i6/152.htm DOI: http://dx.doi.org/10.4329/wjr.v3.i6.152

INTRODUCTION

Duodenal obstruction is a late complication of pancreatic carcinomas and occurs in 10%-15% of cases[1-4]. Palliative surgical intervention for unresectable pancreatic malignancies with a gastrojejunostomy has been associated with increased morbidity and mortality[5]. Palliation with endoscopically or fluoroscopically placed duodenal self-expandable metal stents has been shown to be safe and cost-effective, and improves quality of life in patients with unresectable pancreatic carcinoma and gastric outlet obstruction. A meta-analysis comparing endoscopically placed enteral stents and gastroenterostomy for malignant gastric outlet obstruction showed that endoscopic stenting is associated with higher clinical success, decreased length of stay, shorter time from procedure to oral intake, decreased morbidity, and less delayed gastric emptying compared to the surgical group[6]. This procedure is considered by some as the procedure of choice for malignant gastric outlet obstruction[7] and has been used increasingly in the US. Currently, Wallstent® (Boston Scientific, Natick, MA), an uncovered duodenal stent, is the only stent approved by the Food and Drug Administration in the U.S. for palliation of malignant gastric outlet obstruction[8].

CASE REPORT

A 55-year-old female presented with a 2-wk history of a "viral illness" and a recent onset of painless jaundice with dark colored urine. Her past medical history was significant for colon cancer resected 30 years prior. Physical examination was remarkable only for scleral icterus and jaundice. Laboratory studies were significant for a conjugated hyperbilirubinemia. A computed tomography (CT) scan revealed a 1.5 cm mass in the head of the pancreas with biliary and pancreatic ductal dilatation. Endoscopic retrograde cholangiopancreatogram demonstrated a 2.5 cm stricture that was stented. Brushings revealed carcinoma. An endoscopic ultrasound, biopsy, and staging laparoscopy revealed an unresectable pancreatic carcinoma with encasement of the superior mesenteric vessels. Fifteen months after the initial presentation, the patient developed symptomatic gastric outlet obstruction and underwent endoscopic placement of two 20 mm × 60 mm Wallstent® (Boston Scientific, Natick, MA) stents across the duodenal narrowing.

With failed resolution of her gastric outlet obstructive symptoms, a contrast study was obtained which demonstrated both the biliary stent and the two duodenal stents to be in proper position (Figure 1). Given the ongoing symptoms, a loop gastrojejunostomy was performed without incident. However, on postoperative day 5 the patient developed an acute onset of abdominal pain, acidosis, and leukocytosis. A CT scan revealed a large amount of free fluid in the abdomen, a small amount of free air, and a metallic stent in the distal small bowel (Figure 2). The patient was taken for an emergency exploratory laparotomy where one of the metallic stents was found 10 cm proximal to the ileocecal valve perforating the small bowel. The perforated segment of small bowel was resected along with the stent. However, the patient died 3 d later from multisystem organ failure secondary to overwhelming sepsis.

DISCUSSION

Malignant gastric outlet obstruction is most commonly seen with pancreatic cancer[9]. Traditional palliation with gastroenteric bypass has been shown to be associated with a significant degree of morbidity and mortality[3,5,10]. In recent years, enteral stents placed under endoscopic or fluoroscopic guidance has emerged as an effective, less morbid alternative to surgical intervention. In the US, the enteral Wallstent® (Boston Scientific, Natick, MA) has been approved for duodenal placement for palliation of gastric outlet obstruction[7]. While these stents have many advantages when compared with gastrojejunostomy,

Figure 1 Contrast study prior to the gastrojejunostomy reveals a gastric outlet obstruction with two duodenal stents and a biliary stent in proper position.

Figure 2 Computed tomography scan reveals a stent in the small bowel protruding intra-peritoneally with pneumoperitoneum.

including improved oral nutrition[9,11-13], increased cost-effectiveness[9,14], and decreased morbidity and hospital stay, there is no improvement in 30-d mortality[6]. Despite these advantages, enteral stents are associated with a 17% complication rate including migration, duodenal perforation, biliary enteric fistulas, and reobstruction due to tumor growth and stent fracture[9,11,13].

Although the incidence of clinically significant stent migration is rare, they can cause significant morbidity or mortality when they occur. To our knowledge, there is only one other known report of a palliative duodenal stent migrating to the distal small bowel causing perforation. Reported by Moxey *et al*[15], it occurred 1 mo after a self-expandable stent was placed for presumed pancreatic carcinoma, and was thought to have migrated after the patient's pancreatic inflammation had resolved. The patient underwent a surgical small bowel resection but later expired due to bacterial endocarditis. Other reported stent-related complications described in the literature include stent collapse, bleeding, large-bowel obstruction[16], reobstruction, tumor overgrowth, jaundice, food impaction, and late duodenal perforation[17]. The migration rate of uncovered stents has been reported to be in the range of 0%-11%[11,18,19], compared to 21%-26% for covered stents[20,21].

Given that the stents were confirmed to be in the duodenum prior to the gastrojejunostomy, the migrated stent found during the second exploration must have migrated past the gastrojejunostomy anastomosis to the distal ileum, soon after surgery, leading to the bowel perforation. We presume that the migrated stent may have been dislodged, at least partially, from manipulation during the gastrojejunostomy. The time between the endoscopic placement of the stents and the subsequent gastrojejunostomy was too short to allow for any stabilization of the stents by tumor in-growth or scarring[22].

The enteral Wallstent® has an open mesh and has been associated with insertion difficulties around acute angles as well as damage to tissues and endoscopes by the exposed proximal and distal wires[23]. Sometimes more than one stent is necessary when the first stent is not deployed into the ideal location. The forward force generated by the expanding stent may sometimes lead to undesired forward displacement of the stent, particularly at the site of strictures[22].

In conclusion, we report a rare complication of a duodenal Wallstent® placed for malignant gastric outlet obstruction secondary to pancreatic cancer that migrated to the distal ileum resulting in small bowel perforation. Although uncommon, it is important to be aware of the potential risk of duodenal stent migration, particularly after any manipulation of the stomach or the duodenum during surgery, and especially if the time between stent placement and surgery has been short.

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CASE REPORT

A body-packer with a cocaine bag stuck in the stomach

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Abstract

Management of patients carrying packets of drugs in the digestive tract is a frequent medical problem. We report on a patient who was referred by the police after ingestion of packets of cocaine. After spontaneous elimination of 81 drug packets, the patient had three unremarkable stools. A plain abdominal X-ray disclosed no residual packet but computed tomography (CT) scan showed one in the stomach. As this was not eliminated during the 10 d following ingestion, it was removed through gastrotomy. This case stresses the usefulness of the CT scan to ensure that no residual packet is present before hospital discharge.

Key words: Body-packing; Cocaine; Management; Surgery; Gastroscopy

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INTRODUCTION

Management of patients carrying packets of drugs is a recurrent medical problem. Usually, patients have no complications and current recommendations for such patients advise a conservative approach, waiting for a spontaneous packet's evacuation with the bowel movement. In case of complications such a packet stuck in the stomach, a surgical approach seems to be safer than an endoscopic approach.

Usually plain abdominal X-ray (AXR) is the radiological examination used to detect packets in body-packers and to confirm that all packages have been removed. However, this exam can sometimes miss a packet and bear the risk of missing a diagnosis especially if the packet is stuck and not spontaneously expulsed. Computed tomography (CT) scan is more sensitive than plain abdominal radiography to detect residual packets but is also more expensive, time consuming and delivers more radiation.

CASE REPORT

A 34-year-old man was referred by the police to the emergency room of our hospital for suspicion of drug body packing. The patient admitted having swallowed 82 plastic-wrapped cocaine packets. At admission, he was asymptomatic, his medical history was uneventful, and vital signs and physical exam were normal. Our "body pack" protocol consists, in asymptomatic patients, of starting with plain AXR to detect packets. In unclear cases, additional abdominal CT scan is done. Neither blood tests nor urine drug screening are carried out routinely because they are not of any diagnostic value. Management consists of a conservative approach, waiting for patients to evacuate packets, without use of any laxatives[1,2] because this use might increase complications by inducing a rupture or small lesions of the packages. After having passed three stools without packets we carry out a control X-ray exam which consists of AXR. CT scan is useful for control if there is a discrepancy between results of AXR and the numbers of packets expected to be collected. For detection, current protocols use AXR or CT scan if needed[3-5]. Some propose to screen drugs[4], but there is no consensus with this approach[5]. For management, some authors use laxatives[4,5]. In line with our protocol, in this asymptomatic patient neither blood tests nor urine drug screens were carried out. An AXR showed multiple X-ray dense oval packets in the abdomen compatible with body packing (Figure 1). The patient was kept under surveillance and he uneventfully excreted 81 packets (multi-layered machine-made plastic containers) within 4 d. A rapid test confirmed that these packets contained cocaine. After having passed three stools without packets, the patient had two control X-ray exams: an AXR (Figure 2) and an abdominal CT scan (Figure 3), in accordance with our management protocol. CT scan was performed without oral or intravenous contrast media, using a sixteen multi-row Philips MX 8000 scanner (Philips Medical Systems, Best, The Netherlands), with a reconstruction slice thickness of 5.0 mm, pitch of 1.25, and 0.5-s gantry rotation period. The X-ray tube potential was 120 kV, with a tube charge per gantry rotation of 30 mA. The scanned length was 40 cm. The CT disclosed a single packet localised inside the stomach that was not visible on the AXR. The patient remained asymptomatic and a proton pump inhibitor (esomeprazole 40 mg po *qd*) was administered to reduce the risk of degradation of the bag because of the acidity of the stomach. The CT scan was repeated 3 d later, which again disclosed the container in the stomach. The promotility drug metoclopramide (10 mg po *tid*) was administered to accelerate transpyloric passage of the packet[3]. The cocaine container had not been eliminated after three additional days. A third abdominal CT scan was carried out which concluded that

Figure 1 Abdominal X-ray made at patient admission, showing multiple X-ray dense oval packets in the abdomen compatible with body packing.

Figure 2 Control abdominal X-ray after passage of three stools without packets, showing no residual packet.

Figure 3 Control abdominal computed tomography scan showing a single packet in the stomach that was not visible on the abdominal X-ray.

the cocaine packet was still in the stomach. As more than 10 d had elapsed since packet ingestion, the likelihood of spontaneous elimination was estimated to be low and the packet was extracted through surgical gastrotomy after a small median laparotomy. No complication ensued and the patient was transferred to jail 10 d after surgery.

DISCUSSION

Our protocol concerning the management of body-packers has been used during the past 30 years and consists of a conservative approach: we wait for patients to evacuate packets by normal bowel movements, without use of any laxatives. In 2009, 29 body packers were treated at the prison hospital ward. According to current recommendations[1,2], no treatment other than surgery was administered to the patient. Laxatives were not prescribed to accelerate packets' elimination because the most frequently used laxative, paraffin oil, may favor packet rupture and drug intoxication (mineral oil causes a decrease in strength and flexibility of latex within 15 min)[6,7]. However, we acknowledge that the risk of rupture is much lower with modern, multilayered (type 4), packets similar to those found in this patient[8], and that paraffin oil has been systematically administered in a series of 573 body-packers with a low (1%) rupture rate[9].

Endoscopic extraction was not attempted as endoscopic manipulation of such packets may result in rupture and the cocaine content of a single packet exceeds the lethal dose. To our knowledge, only three cases of successful endoscopic extraction of cocaine packets from the upper digestive tract have been reported, all of these in patients who had refused surgery[10-12]. Our patient provided informed consent prior to surgery.

Usually, AXR is used to detect body-packers. In our case, CT scan disclosed a remaining packet in the stomach that was undetected at AXR. The sensitivity of AXR for packet detection is approximately 85%-90%[13]. There is evidence that an abdominal CT scan is better than AXR to detect residual packets[14]. Management to identify residual body-packers should balance the diagnostic superiority of abdominal CT scan, the risks of medical complications if containers are not detected with AXR, but also the higher radiation delivery and cost of abdominal CT scan. There isn't much literature about methods to detect drug packets avoiding exposure to radiation such as ultrasound[15,16] and magnetic resonance imaging[17]. Current protocols recommend the use of AXR to confirm packet retention and, in case of doubt, the use of abdominal CT scan with reduced mAs, delivering a dose of radiation close to that of an AXR[4,18]. Therefore, it is our practice to perform an AXR after elimination of three packet-free stools, followed by a CT scan in cases where suspicion of retained packets is high despite a negative AXR.

In conclusion, according to our experience, management of asymptomatic body-packers should first be conservative. In case of complications, such as packet rupture or intestinal obstruction, surgery - and not endoscopy - is the method to use. Although newer package types used for concealment of drugs inside the abdomen are more resistant, we think that surgical extraction remains the safest extraction procedure in cases of retention.

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AUTOBIOGRAPHY OF EDITORIAL BOARD MEMBERS

Rui Liao's work on patient-specific 3-D model guidance for interventional and hybrid-operating-room applications

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Abstract

Compared to surgery, interventional and hybrid-operating-room (OR) approaches diagnose or treat pathology with the most minimally invasive techniques possible. By minimizing the physical trauma to the patient, peripheral or hybrid approaches can reduce infection rates and recovery time as well as shorten hospital stays. Minimally invasive approaches therefore are the trend and often the preferred choice, and may even be the only option for the patients associated with high surgery risks. Common interventional imaging modalities include 2-D X-ray fluoroscopy and ultrasound. However, fluoroscopic images do not display the anatomic structures without a contrast agent, which on the other hand, needs to be minimized for patients' safety. Ultrasound images suffer from relatively low image quality and tissue contrast problems. To augment the doctor's view of the patient's anatomy and help doctors navigate the devices to the targeted area with more confidence and a higher accuracy, high-resolution pre-operative volumetric data such as computed tomography and/or magnetic resonance can be fused with intra-operative 2-D images during interventions. A seamless workflow and accurate 2-D/3-D registration as well as cardiac and/or respiratory motion compensation are the key components for a successful image guidance system using a patient-specific 3-D model. Dr. Liao's research has been focused on developing methods and systems of 3-D model guidance for various interventions and hybrid-OR applications. Dr. Liao's work has led to several Siemens products with high clinical and/or market impact and a good number of scientific publications in leading journals/conferences on medical imaging.

Key words: Angiography and fluoroscopy; Augmented reality; Hybrid-operating-room applications; Image-guided interventions; Motion compensation; 2-D/3-D fusion; 2-D/3-D registration; X-ray

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INTRODUCTION AND EDUCATIONAL EXPERIENCE

Dr. Rui Liao is a senior research scientist at Siemens Corporate Research, Princeton, NJ USA. She received a B.Sc in Electrical Engineering and Automation from Tianjin University (formerly known as Bei Yang University, the first university in China) in 1997, with the highest honor. She obtained her MSc from Nanyang Technological

University (Singapore) in 2000, and her PhD from Duke University (USA) in 2004, both in Electrical Engineering (minor in Biomedical Engineering). Dr. Liao was then employed as a research scientist and later a senior research scientist by Siemens Corporate Research, Princeton, NJ, USA. Her research interests are in the broad area of signal/image processing and biomedical imaging, with the focus on image-guided interventions and hybrid-OR applications.

Dr. Liao was interviewed by Siemens Picture of The Future (PoF) Magazine (http://www.siemens.com/innovation/en/publications/pof_fall_2010/demographic_change/cardio.htm) for her instrumental contribution to the Aortic ValveGuide technology that won EACTS Techno-College Innovation Award 2010 and Siemens Top+ Innovation Award 2010 (http://www.ehealthnews.eu/siemens/2259-siemens-wins-2010-techno-college-innovation-award). Dr. Liao has co-authored over 60 journal/conference papers and patent applications, and received the Young Investigator Award on ISBI 2004, and co-authored the runner-up of Young Scientist Award on MICCAI 2009. Dr. Liao is currently on the editorial board of The Open Biomedical Engineering Journal and World Journal of Radiology, and has consistently been on the reviewing committee for major journals and conferences in medical imaging and image processing.

ACADEMIC STRATEGY AND GOALS

Over the last 6 years, Dr. Liao's research has been focused on image processing and medical imaging for image-guided interventions and hybrid-OR applications. During interventions, patient-specific medical images are acquired intra-operatively to monitor the procedures, and to provide road maps that allow the interventional radiologist to insert the interventional devices *via* small incisions in the patient and navigate them through the body to the target area with disease. Minimally invasive approaches have rapidly gained popularity in recent years. For example, percutaneous stenting has now largely replaced coronary artery bypass grafts (once the gold standard), and there is a huge movement from open heart valve surgery toward minimally invasive trans-catheter heart valve repair. Dr. Liao proposed multiple innovative 2-D/3-D registration and motion compensation technologies to bring patient-specific 3-D models into the operating room, including learning-based, spine-based, curve-based, graph-based, location constraint-based, lasso-based, motion model-based, and hybrid models. The proposed methods significantly improved the robustness and accuracy of 2-D/3-D fusion for various applications, which in turn provides more accurate anatomical details and further enhances physicians' confidence in device navigation and deployment during interventions. Dr. Liao has led and/or participated in multiple 2-D/3-D fusion prototyping projects for X-ray and magnetic resonance (MR)-based interventions and hybrid-OR applications, including trans-catheter aortic valve implantation (TAVI), abdominal aortic aneurysm (AAA) stenting, electrophysiology radio-frequency catheter ablation (RFCA), and chronicle total occlusion (CTO) revascularization.

ACADEMIC ACHIEVEMENTS

2-D/3-D fusion and motion compensation for TAVI

Aortic valve disease affects 1.8% of the global population and is the most frequent heart valve disease in Western countries, leading to 60 000 surgical aortic valve replacements every year in Europe and even more in the United States[1]. TAVI is a new and breakthrough minimally invasive surgery. During trans-apical TAVI, an antegrade access is used where the catheter and the prosthesis are inserted *via* small incisions in the chest and the apex of the left ventricle. During trans-femoral TAVI, the catheter is inserted retrogradely *via* the femoral artery and the aortic arch. Both approaches require X-ray angiographic and fluoroscopic imaging to guide the procedure.

Prior to implantation it is important to angulate the C-arm of the interventional X-ray machine with respect to the patient's aortic root anatomy. Usually, an appropriate angulation is achieved with iterated C-arm angulations, each followed by an angiogram with approximately 15 mL contrast agent to double-check the aortic root position. Further angiograms are needed later on for correct prosthesis positioning and for functional control after implantation. Recently, we proposed to support TAVI procedures using 3-D models from interventional C-arm computed tomography (CT) volume by overlaying the 3-D aortic model onto fluoroscopy to provide anatomical details and more automatic and accurate C-arm angulation for optimal valve deployment[2].

A hybrid 2-D/3-D registration method to align the 3-D model and 2-D angiography for TAVI procedures was proposed in[3] (Figure 1). The proposed hybrid method incorporates the segmentation and landmark information of the 3-D aortic root into intensity-based registration for highly accurate and robust 2-D/3-D alignment of the aorta. Both the 3-D volume and the 2-D images are captured with contrast injection showing the patient' s aortic root. 2-D angiographic images are first pre-processed to remove the background and/or devices such as the catheter and TEE probe. 3-D aorta segmentation and coronary ostia landmark detection is performed on the 3-D C-arm CT volume using the learning-based method presented in[4]. Aorta segmentation is then used to produce clean digitally reconstructed radiographs (DRRs) that show only the aorta and excludes all the peripheral structures such as the spine. Landmarks representing the left and right coronary ostia are further utilized in an integrated fashion with the intensity-based method. A multi-layer and multi-resolution optimization strategy is finally deployed to find the optimal registration.

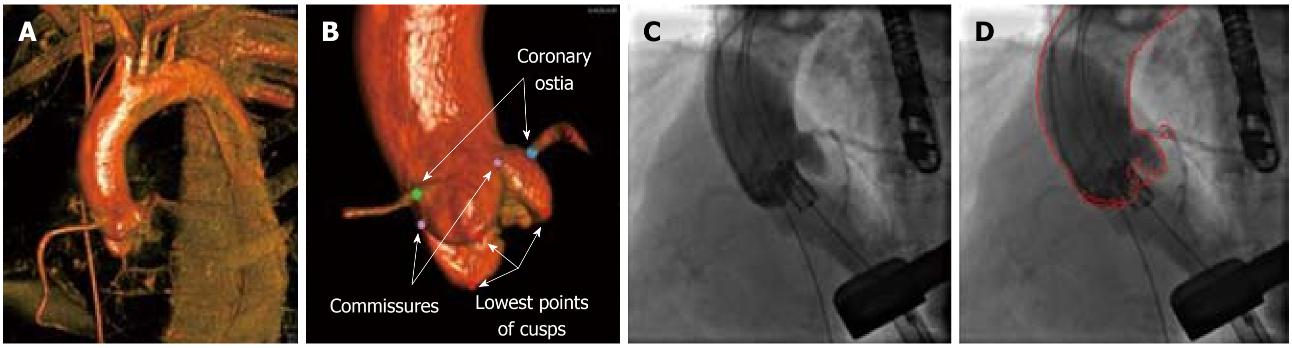

Figure 1 Registration of 3-D volume and 2-D angiography of a patient's aorta[3]. A: The original 3-D volume; B: Aorta segmentation and coronary ostia landmark detection; C: Aortic angiography; D: Overlay of aortic angiography with the contour of the 3-D model after registration.

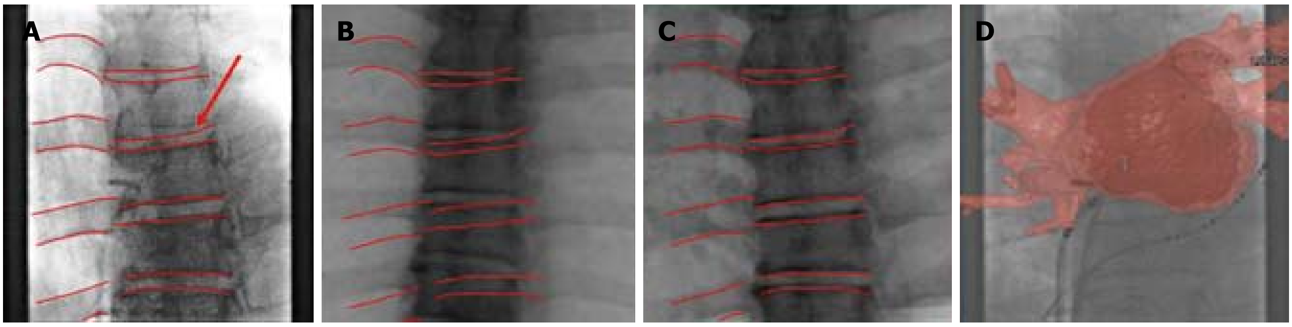

Figure 2 Spine-based 2-D/3-D registration examples for electrophysiology[9]. A: Spine-enhanced fluoroscopy with the edge contours depicted; B: Digitally reconstructed radiographs (DRRs) before registration overlaid with the edge contours from fluoroscopy; C: DRRs after registration overlaid with the edge contours from fluoroscopy; D: 2-D/3-D overlay used for electrophysiology procedures. The 3-D mesh model is generated from the segmentation of the left atrium and pulmonary veins, and is overlaid with fluoroscopy by the proposed spine-based 2-D/3-D registration technique.

Our system needs to be set up in the complex environment of a hybrid operating room and used by a physician during a highly complicated hybrid-OR application that involves a large number of staff, equipment and steps. Therefore, it is crucial for the acceptance of such a system to be fast, to minimize the user interaction and to allow table-side control. Fast and automatic contrast detection in the aortic root on X-ray images facilitates a seamless workflow to utilize the 3-D models by triggering 2-D/3-D registration automatically when motion compensation is needed. In[5], we proposed a novel method for automatic detection of contrast injection in the aortic root on fluoroscopic and angiographic sequences. The proposed method is based on histogram analysis and likelihood ratio test, and is robust to variations in the background, the density and volume of the injected contrast, and the size of the aorta. The performance of the proposed algorithm was evaluated on 26 sequences from 5 patients and 3 clinical sites, with 16 out of 17 contrast injections correctly detected and zero false detections.

2-D/3-D Fusion and motion compensation for RFCA

Atrial fibrillation (AFIB) is a leading cause of stroke and one of the most common heart rhythm disorders. RFCA has become an accepted option for treating AFIB in today's electrophysiology (EP) labs, especially if drug treatment has become ineffective. In order to guide the process of finding the site of origin where the excess firing of cells occur, 2-D X-ray fluoroscopy has been routinely used to provide real-time monitoring of EP procedures. Unfortunately X-ray projection images cannot distinguish soft tissue well. To address this issue, fused visualization combining pre-operative high-resolution 3-D atrial CT and/or MR volumes with the fluoroscopic images has been developed (fluoro overlay image guidance)[6].

Registration between 3-D volumes and 2-D fluoroscopic images for EP is a challenging task due to the fact that there are few discernable features in a typical EP fluoroscopic image. Rhode *et al*[7] proposed to use multimodality fiducial skin markers to register MR volumes with X-ray images. This method, however, requires specialized markers as well as a specialized workflow to guarantee that the markers are applied at the same position between the pre- and intra-operative data. We further proposed to utilize the coronary sinus (CS) and the catheter placed inside the CS as a location constraint to perform 2-D/3-D registration[8]. This method is not applicable when a CS catheter is not used during the procedure. In[9] we designed an accurate and workflow-friendly spine-based 2-D/3-D registration technique to align C-Arm CT volume and fluoroscopic images to compensate for patient movement in EP (Figure 2). The spine is a natural landmark with rich geometric variations that can be used for accurate registration. The proposed method can be applied when C-Arm CT volume is available for bringing the pre-operative CT/MR volume into alignment with the patient *via* 3-D/3-D registration, or when C-Arm CT is used in place of CT/MR for interventional guidance. To our knowledge, this is the first fully-automatic intensity-based 2-D/3-D registration method that is designed and tested for EP, without the requirement for contrast agent injection.

Static overlay techniques do not follow the heart while it beats and moves through the breathing cycle. This effect may impair the utility of fluoroscopic overlays for catheter navigation. By synchronizing the fluoroscopic images with an electrocardiogram (ECG), cardiac motion can be eliminated, and respiratory motion can be isolated for the fused visualization. While it has been widely recognized that motion compensation is crucial for fluoroscopic overlays, image-based 3-D motion-compensation methods designed for EP applications are very challenging because there are few discernible features in EP fluoroscopic images. Motion compensated navigation for coronary intervention using magnetic tracking was suggested in[10], but it requires special catheters equipped with an electromagnetic sensor at increased cost. Only vertical motion in the imaging plane was compensated in[11] and[12] for liver embolization and hepatic artery catheterization, respectively. In general, though, this is not sufficient for EP breathing motion compensation because the left atrium undergoes three dimensional motions during respiration, as shown in[13].

In[14-16] we described an image-based method to detect and compensate respiratory motion in 3-D for EP procedures using a biplane C-arm fluoroscopy device (Figure 3). Such an X-ray system has two imaging planes commonly referred to as A-plane and B-plane, respectively. To perform motion estimation, we track a commonly available EP catheter, the ring-shaped lasso catheter. Since this device is often used for pulmonary vein (PV) ablations, there is no need for additional instruments or fiducial markers. In addition, the lasso catheter is a unique shape and is one of the most prominent structures shown in EP fluoroscopy, representing a good feature for robust tracking. During isolation of the four PVs during AFIB ablation, the lasso catheter is typically fixed at the ostium of the PV that is to be ablated. By tracking the lasso catheter, we can obtain a motion estimate right at the ablation site. The motion estimation takes place directly in 3-D and not in 2-D. Once an estimate of the 3-D motion is available, we can apply it to the static fluoroscopic overlay to generate an animated representation. To the best of our knowledge, this is the first image-based method that is specifically designed for the challenging task of 3-D breathing motion compensation during EP applications.

A biplane system is less common than a monoplane system due to its much higher cost, and involves increased radiation for both the patient and the clinician[34]. In[17], we further investigated the feasibility of tracking in the monoplane fluoroscopy the circumferential lasso catheter using a B-spline-based method. The tracking results are then used for the estimation of the 3-D breathing motion trajectory and for subsequent motion compensation in a monoplane setup. The performance of the proposed tracking algorithm was evaluated on 340 monoplane frames with an average error of 0.68 ± 0.36 mm. Our contributions to this work are two-fold. First and foremost, we showed how to design an effective, practical, and workflow-friendly 3-D motion compensation scheme for EP procedures in a monoplane setup. In addition, we developed an efficient and accurate method for model-based tracking of the circumferential lasso catheter in low-dose EP fluoroscopy.

2-D/3-D fusion and motion compensation for CTO revascularization

Percutaneous coronary intervention (PCI) of coronary arteries is a common procedure in cardiology intended to provide functional revascularization of stenosed (narrowed) or occluded coronary vessels[18]. Although PCI is commonly performed on patients diagnosed with coronary diseases, many cases remain highly challenging due to the complex 3-D topology of the coronary arteries (e.g. tortuous vessels) and their limited visibility due to stenosed and/or heavily calcified vessels on X-ray fluoroscopy. Hence, navigation in the coronary pathways can be very difficult, since the vessel's depth is mentally estimated by the cardiologist from a monoplane 2-D image. Biplane fluoroscopic systems are actually proposed to overcome vessel foreshortening and to provide accurate navigation guidance, but their availability in today' s clinical setting and the additional radiation exposure for the patient are two major inconveniences. A third inconvenience during PCI is that contrast agent injection has to be used to highlight the targeted vessel. Ideally, this should be minimized during the overall procedure and used only at key steps of the intervention. Consequently, guidance during PCI relies extensively on the cardiologist's experience to advance a guide wire without perforating the boundary of the vessel wall, using a monoplane fluoroscopic view.

Preoperative soft tissue imaging is evolving rapidly and becoming more accepted prior to PCI, to provide insights about the vessel 3-D morphology. Multi-slice computed tomography (MSCT) is proposed to delineate in 3-D the vessel centerline, vessel wall and most importantly, the MSCT volumetric intensities corresponding to plaque or calcification. An intra-operative overlay of this information onto fluoroscopy could provide valuable guidance cues to cardiologists currently unavailable on

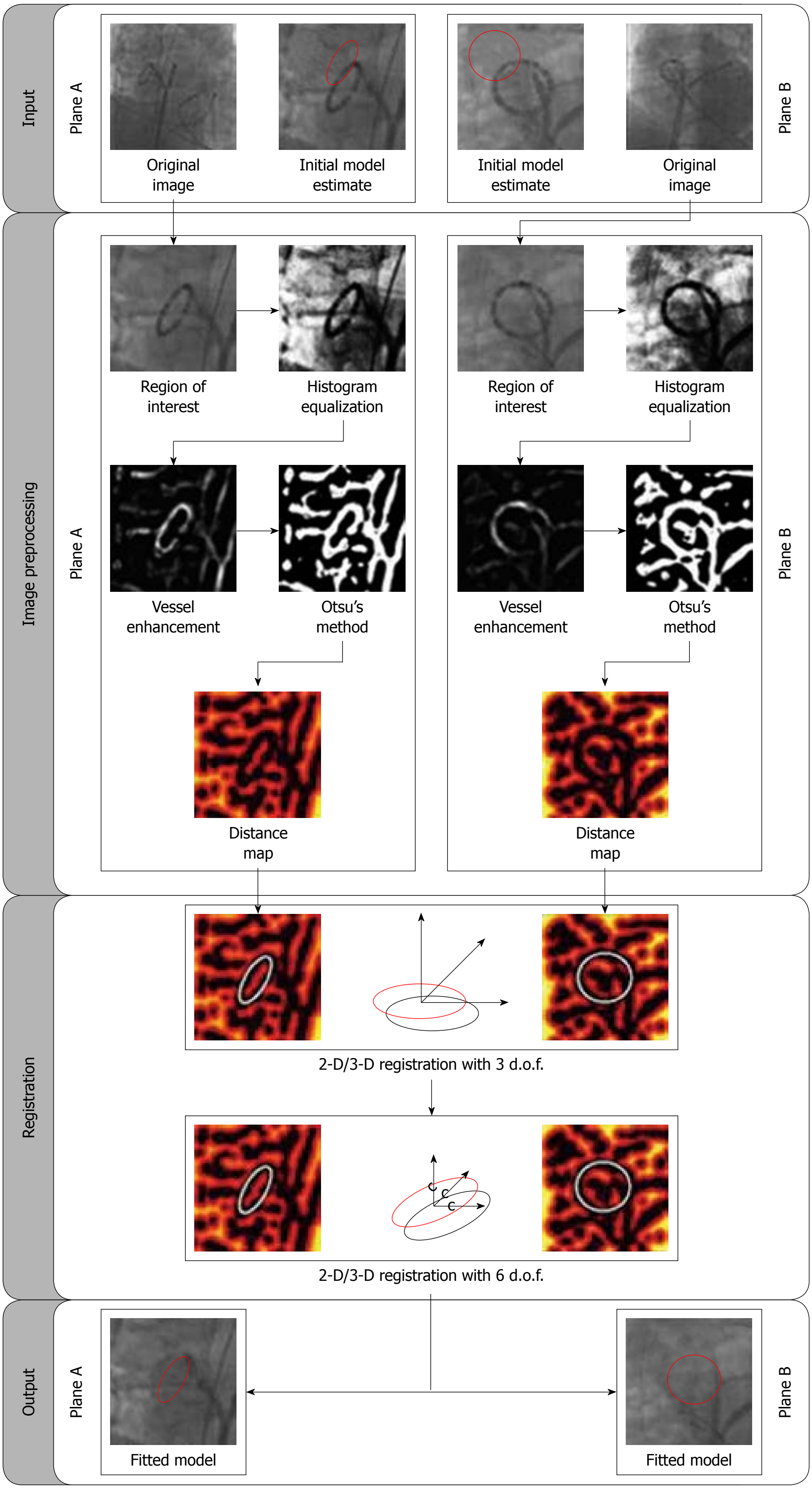

Figure 3 Workflow of image processing and 2-D/3-D registration for lasso catheter-based motion compensation for electrophysiology radio-frequency catheter ablation[15].

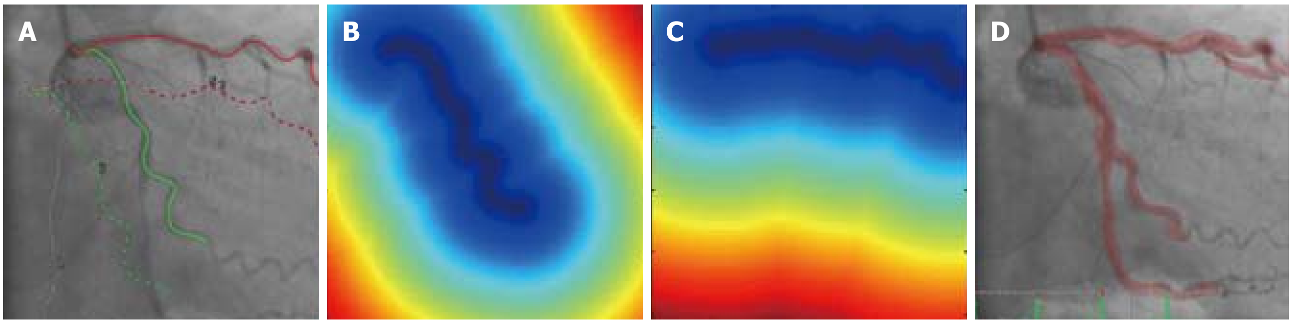

Figure 4 Curve-based 2-D/3-D registration for chronicle total occlusion revascularization[21]. A: Curves of the LCx (green) and LAD (red) identified on fluoroscopic images (in bold) using a semi-automatic tool based on the vesselness measure, fast marching, and B-Spline fitting. The 2-D projection of the corresponding curve segments from the 3-D multi-slice computed tomography (MSCT) is shown with an offset (in dashed). The image frame used for registration is selected to match the acquisition cardiac phase of the MSCT volume, expressed by a percentage of the R-R interval from the electrocardiogram; B, C: The distance transform image obtained from the curve identified on the LCx and the LAD; D: Registration results obtained by selecting the LCx and LAD. The mesh model of the segmented MSCT is overlaid on top of the fluoroscopic image after registration.

fluoroscopic images.

Two categories of 2-D/3-D registration techniques were proposed for coronary registration: landmark-based and intensity-based registration. Intensity-based registration was previously proposed to align a full coronary artery tree from a biplane system to fuse CT or MR to angiograms[19]. This method can be computationally expensive and more importantly lack the flexibility to target specific structures to align. Landmarks can be introduced to focus the registration process on a specific anatomical structure, but are subject to the number, spatial location and proper identification of landmarks. For instance, bifurcation points of the coronary artery tree are generally used for that purpose[20], but are not always visible due to vessel foreshortening.

In[21], we proposed a novel registration workflow involving specific coronary artery branches to align MSCT acquisition with X-ray fluoroscopy (Figure 4). Since coronary vessels are long, continuous and elongated structures, a curve-based technique is appealing for geometric representation of coronary vessels and has been previously proposed for coronary 3-D reconstruction[22]. In addition, our proposed method incorporates automatic ECG gating for cardiac motion compensation, and respiratory motion is further compensated by rigid body registration of the vessels. The coronary vessels are first segmented from a MSCT volume and corresponding vessel segments are identified on a single gated 2-D fluoroscopic frame. Registration can be explicitly constrained using one or multiple branches of a contrast-enhanced vessel tree or the outline of the guide wire used to navigate during the procedure. Finally, the alignment problem is solved by the Iterative Closest Point algorithm. To be computationally efficient, a distance transform is computed from the 2-D identification of each vessel such that distance is zero on the centerline of the vessel and increases away from the centerline.

In[23], we further proposed and validated a PCA-based respiratory motion model for more robust and efficient breathing motion compensation during CTO revascularization. In a preparatory training phase, a preoperative 3-D segmentation of the coronary arteries is automatically registered with a cardiac gated biplane cineangiogram, and then used to build a respiratory motion model. This motion model is subsequently used as a prior within the intra-operative registration process for motion compensation to restrict the search space. Our hypothesis is that the use of this model-constrained registration increases the robustness and registration accuracy, especially for weak data constraints such as low signal-to-noise ratio, the lack of contrast information, or an intra-operative monoplane setting. This allows for reducing radiation exposure without compromising on registration accuracy. Experimentally, we were able to significantly accelerate the intra-operative registration with a 3-D error of less than 2 mm for both monoplane images and intra-procedure settings with missing contrast information based on 2-D guide wire tracking, which makes it feasible for motion correction in clinical procedures.

3-D reconstruction of the coronary artery tree from a rotational X-ray angiography

The gold standard for diagnosis of cardiovascular disease is X-ray coronary angiography, which gives 2-D projection images of the complex coronary artery tree. Therefore, a significant amount of 3-D information of the underlying coronary arteries is lost by the 2-D projection simplification. Traditionally, several angiographic views are taken from different angles and then are selected subjectively based on the cardiologist's experience, to minimize foreshortening and vessel overlap. However, this is associated with a high intra-observer variability and increased radiation/contrast injection. Green *et al*[24] found that vessel shortening was markedly greater in expert-recommended views than in computer-generated views.

3-D symbolic reconstruction of coronary arteries from angiographic images was investigated using two projections[25,26], either from a fixed biplane system, or

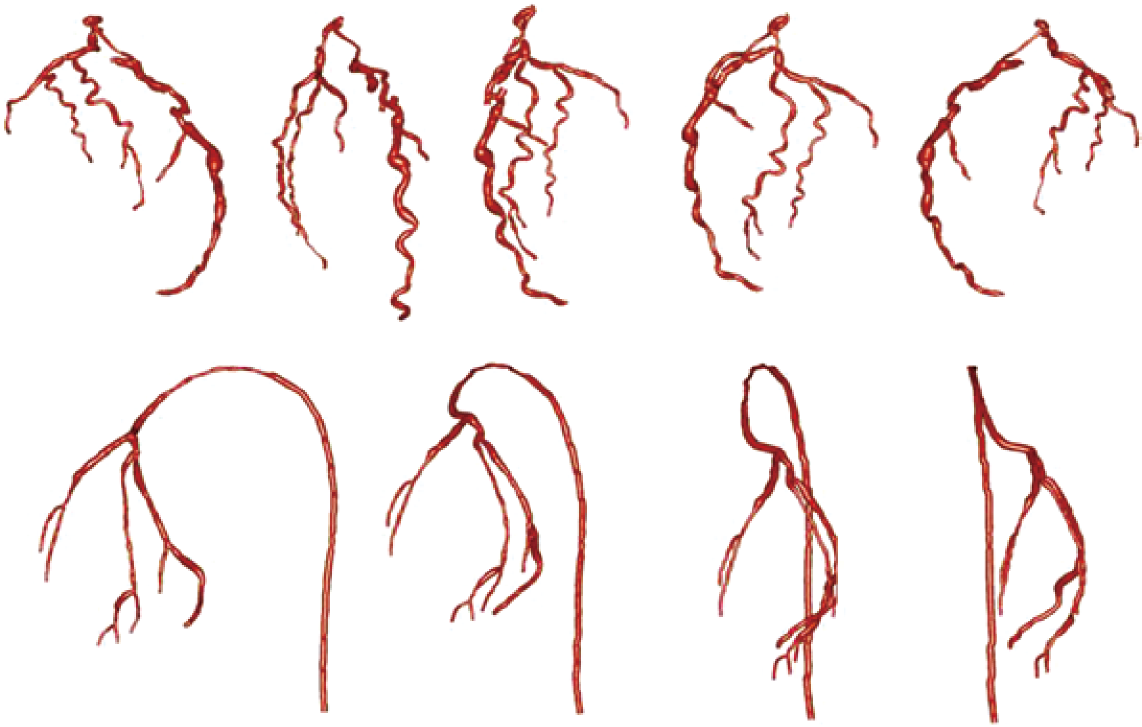

Figure 5 Two examples of 3-D reconstruction of the coronary artery tree from an X-ray rotational angiography viewed at different angles[28].

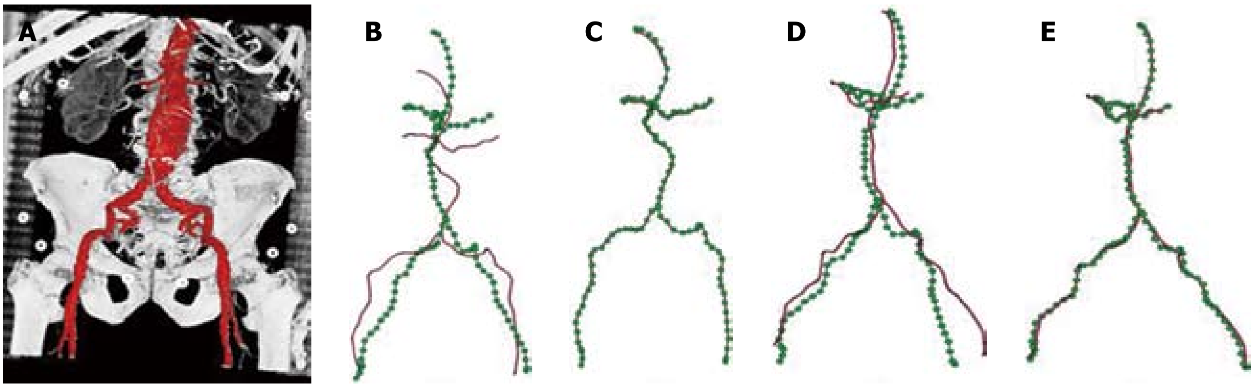

Figure 6 Graph-based deformable 2-D/3-D registration for abdominal aortic aneurysm stenting[30]. A: An example of patient computed tomography data, with abdominal aortic aneurysm segmented and shown in mesh; B: The 3-D graph and the ground truth with synthesized deformation for patient one; C: Registration results of (B); D: The 3-D graph and the ground truth with natural deformation for patient two; E: Registration result of (D).

from different projections on a monoplane C-Arm. However, 3-D reconstruction of the complex 3-D topology of coronary vessels using only two 2-D projections is often not sufficient to obtain a precise reconstruction. The extracted 2-D vessel centerlines may not be complete or accurate due to the flow of the dye, low image contrast, or superposition of vessels in a certain view. In addition, whereas typically it is preferred to have two projections orthogonal to each other, this angular distance may not be achievable in a clinical setup when foreshortening and vessel overlap need to be minimized for the whole coronary artery tree in both projections. Another limitation is that corresponding vessels between the two views can be established typically only through user interaction.

The goal of our papers[27,28] is to describe an efficient and robust method for 3-D model generation of the coronary artery tree using all the projections of a rotational X-ray sequence that correspond to the same cardiac phase (Figure 5). A rotational X-ray sequence is acquired by rotating the C-arm with a constant source to intensifier distance, a constant cranio/caudal angle, and a varying left/right anterior oblique angle. Depending on the rotation speed and the heart rate of the patient, a rotational X-ray sequence may cover 5 to 8 cardiac cycles. 2-D coronary artery centerlines are extracted automatically from X-ray projection images using an enhanced multi-scale analysis. For difficult data with low vessel contrast, a semi-automatic tool based on a fast marching method is

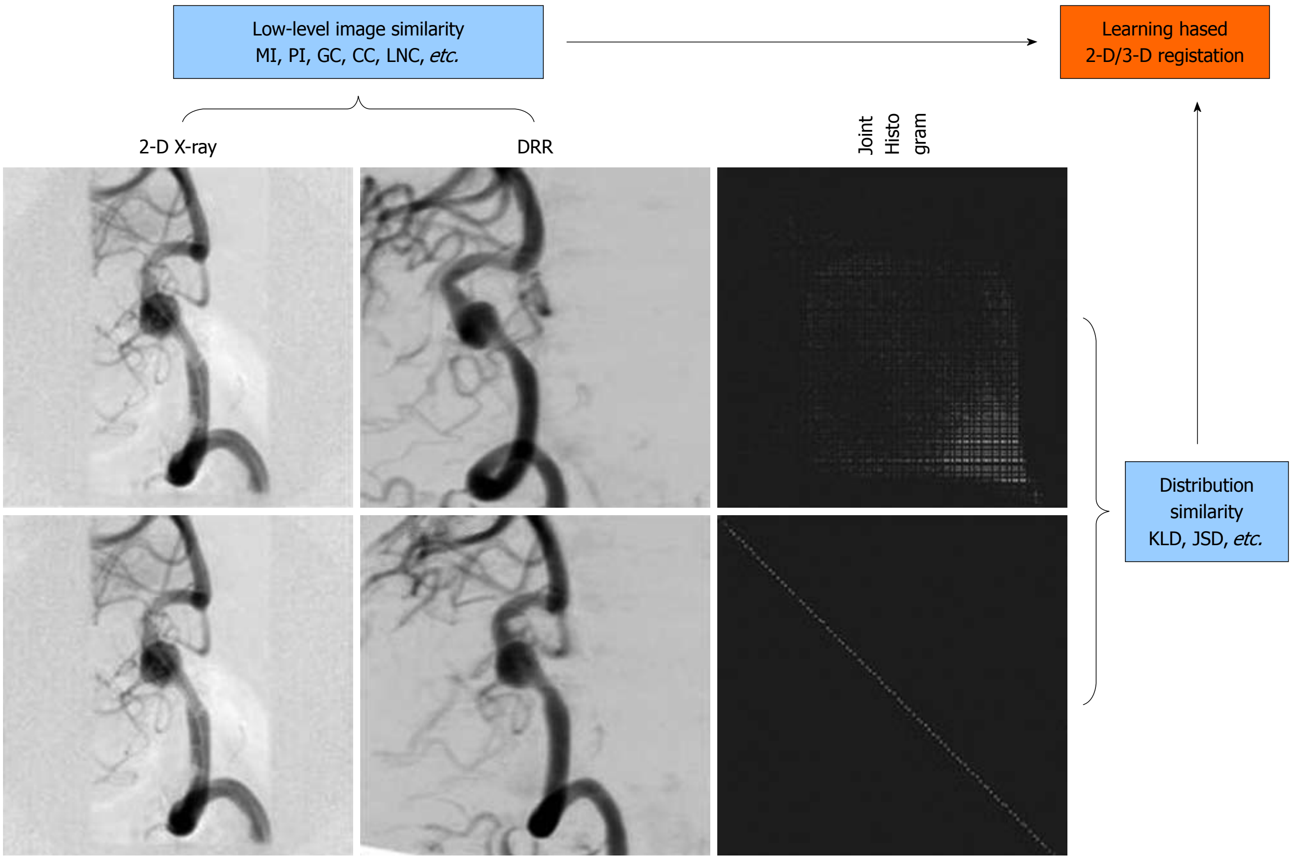

Figure 7 Learning-based 2-D/3-D registration[33]. DRR: Digitally reconstructed radiograph.

implemented to allow manual correction of automatically-extracted 2-D centerlines. We then formulated the 3-D symbolic reconstruction of coronary arteries from multiple views as an energy minimization problem incorporating a soft epipolar line constraint and a smoothness term evaluated in 3-D. The proposed formulation results in the robustness of the reconstruction to the imperfectness in 2-D centerline extraction, as well as the reconstructed coronary artery tree being inherently smooth in 3-D. We further proposed to solve the energy minimization problem using α-expansion moves of Graph Cuts[29], a powerful optimization technique that yields a local minimum in a strong sense at a relatively low computational complexity.

We showed experimental results on a synthetic coronary phantom, a porcine data set and 11 patient data sets. For the coronary phantom, results obtained using a different number of views were presented. 3-D reconstruction error evaluated by the mean plus one standard deviation is below one millimeter when 4 or more views are used. For real data, reconstruction using 4 to 5 views and 256 depth labels averaged around 12 s on a computer with 2.13 GHz Intel Pentium M and achieved a mean 2-D back-projection error of 1.18 mm (ranging from 0.84 to 1.71 mm) in 12 cases. With significant improvements in efficiency, our method is promising in terms of clinical usability. The most straightforward application of our method in a clinical setup would be to provide the reconstructed 3-D coronary model to the interventional cardiologists at the beginning of the PCI procedures. The 3-D model visualization will help clinicians to choose optimal angiographic views to minimize vessel foreshortening, select proper stent type and size, and properly plan the stent placement 3-D locations.

Advanced 2-D/3-D registration: Deformable and learning-based

AAA is the local expansion of the abdominal aorta. There is a risk of rupture of the aneurysm if the expansion becomes large enough, and the chance of post-rupture survival for such patients is low. AAA is currently ranked as the 13th leading cause of death in the U.S. In recent years, minimal-invasive interventional repairs are rapidly emerging as an alternative to open surgeries for the treatment of AAA, especially for patients at increased surgical risk due to age or other medical conditions. Due to the deformable nature of the abdominal organs, there typically exist elastic deformations between pre-operative volumes and intra-operative X-ray images. The insertion of the medical devices into the artery during AAA procedures can further introduce significant deformations to the target vessel that needs to be aligned. Therefore, a rigid-body 2-D/3-D registration scheme is typically not sufficient for AAA stenting applications, and an advanced deformable 2-D/3-D registration method needs to be developed here.

In[30], we proposed to formulate the deformable 2-D/3-D registration problem on a 3-D graph, and further provided an efficient numerical solution to the graph-based formulation (Figure 6). In particular, a 3-D graph is generated from the abdominal aorta segmented from the pre-operative MSCT data, and a 2-D distance map is generated from each of the 2-D X-ray images used for registration. A distance map is a smooth shape encoding of the underlying structures, and by utilizing a distance map, explicit establishment of corresponding points between 2-D and 3-D graphs can be avoided during the optimization. This reduces the optimization space to a much lower dimension. In addition, smoothness calculation is defined on the 3-D graph, the derivative of which can be calculated efficiently using the well-known Laplacian matrix of a graph.

Specific to the anatomy of the abdominal aorta, a hierarchical registration scheme was further deployed. In particular, the 3-D graph is divided into three segments, renal arteries, iliac arteries, and abdominal aorta. A piecewise rigid-body transformation is first applied individually to the three segments while their connectivity is maintained. Local deformation is then estimated for the complete graph comprising all three segments. We further compared the registration accuracy achieved by using one and two views. We showed that even with the incorporation of a length-preserving term, a single projection image alone can only produce accurate registration in the imaging plane, while two views are required in order to achieve accurate registration in 3-D. The method was validated using both phantom and clinical datasets, and achieved an average error of < 1 mm within 0.1 s. The extremely high efficiency further opens the door to many potential applications. For example, the weight for each term in the energy functional is data-dependent. Our runtime of 0.1 s makes it feasible to obtain the optimal combination of weights interactively for a given dataset, even during interventions. The proposed method is of general form and has the potential to be applied in a wide range of applications requiring efficient deformable 2-D/3-D registration of vascular structures.

In recent years, learning-based methods have been suggested for general medical registration to impose prior knowledge to achieve more robust and reliable registration[31]. Learning-based methods were further extended to 2-D non-rigid image registration in[32] where the Kullback-Leibler divergence (KLD) w.r.t., a prior joint distribution, was minimized together with the maximization of the mutual information measure.

In[33], we proposed a Jensen-Shannon divergence (JSD)-based method for learning-based 2-D/3-D registration (Figure 7). Unlike KLD, JSD is symmetric, bounded, and a true metric, which has triggered its popularity in various applications in recent years, ranging from statistical language analysis, image edge detection and segmentation, to DNA sequence analysis. Therefore, JSD provides a more suitable measure than KLD in quantifying histogram discrepancy because some histogram bins may vanish for the training data but not for the observed data or *vice versa*, in which case KLD is undefined. Furthermore, JSD is upper-bounded and symmetric, facilitating its easy use as one of the factors in the driving force for registration.

Other advantages of our method include: (1) Depending on how well the *a priori* represents the observed data, the registration process is driven by a compounding effect of the statistical consistency of the observed joint histogram to the learned prior, and the statistical dependence between the individual intensity distributions of the images being registered; (2) There is no requirement on image segmentation and labeling, whose error can lead to further errors in subsequent registration. Instead, automatic nonlinear histogram mapping is done iteratively during the matching process to handle the intensity discrepancy between the observed data and the training data; and (3) An intensity-based histogram is used, which is supposed to result in a higher registration accuracy than the case where a class-based histogram was used in the argument of a higher computational efficiency in the generation of DRRs. Instead we deployed highly efficient GPU-based DRR generation for a speed-up. Experimental results demonstrated that a combination of the prior knowledge and the low-level similarity measure between the images being registered led to a more robust and accurate registration in comparison with the cases where either of the two factors was used alone as the driving force for registration.

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MEETINGS

Events Calendar 2011

January 23-27
Radiology at Snowbird
San Diego, Mexico

January 24-28
Neuro/ENT at the Beach
Palm Beach, FL, United States

February 28-29
MIAD 2011 - 2nd International Workshop on Medical Image Analysis and Description for Diagnosis System
Rome, Italy

February 5-6
Washington Neuroradiology Review
Arlington, VA, United States

February 12-17
MI11 - SPIE Medical Imaging 2011
Lake Buena Vista, FL, United States

February 17-18
2nd National Conference Diagnostic and Interventional Radiology 2011
London, United Kingdom

Februrary 17-18
VII National Neuroradiology Course
Lleida, Spain

February 18
Radiology in child protection
Nottingham, United Kingdom

Februrary 19-22
COMPREHENSIVE REVIEW OF MUSCULOSKELETAL MRI
Lake Buena Vista, FL, United States

March 2-5
2011 Abdominal Radiology Course
Carlsbad, CA, United States

March 3-7
European Congress of Radiology Meeting ECR 2011 Vienna, Austria

March 6-9
World Congress Thoracic Imaging - IV
Bonita Springs, FL, United States

March 14-18
9th Annual NYU Radiology Alpine Imaging Symposium at Beaver Creek
Beaver Creek, CO, United States

March 20-25
Abdominal Radiology Course 2011
Carlsbad, CA, United States

March 26-31
2011 SIR Annual Meeting
Chicago, IL, United States

March 28-April 1
University of Utah Neuroradiology 2nd Intensive Interactive Brain & Spine Imaging Conference
Salt Lake City, UT, United States

April 3-8
1st Annual Ottawa Radiology Resident Review
Ottawa, Canada

April 3-8
43rd International Diagnostic Course Davos on Diagnostic Imaging and Interventional Techniques
Davos, Switzerland

April 6-9
Image-Based Neurodiagnosis: Intensive Clinical and Radiologic Review, CAQ Preparation
Cincinnati, OH, United States

April 28-May 1
74th Annual Scientific Meeting of the Canadian Association of Radiologists CAR
Montreal, Canada

May 5-8
EMBL Conference-Sixth International Congress on Electron Tomography
Heidelberg, Germany

May 10-13
27th Iranian Congress of Radiology
Tehran, Iran

May 14-21
Radiology in Marrakech
Marrakech, Morocco

May 21-24
European Society of Gastrointestinal and Abdominal Radiology 2011 Annual Meeting
Venice, Italy

May 23-25
Sports Medicine Imaging State of the Art: A Collaborative Course for Radiologists and Sports Medicine Specialists
New York, NY, United States

May 24-26
Russian Congress of Radiology
Moscow, Russia

May 28-31
International Congress of Pediatric Radiology (IPR)
London, United Kingdom

June 4-8
58th Annual Meeting of the Society of Nuclear Medicine
San Antonio,
TX, United States

June 6-8
UKRC 2011 - UK Radiological Congress
Manchester, United Kingdom

June 8-11
CIRA 2011 - Canadian Internventinal Radiology Association Meeting
Montreal, QC, Canada

June 9-10
8th ESGAR Liver Imaging Workshop
Dublin, Ireland

June 17-19
ASCI 2011 - 5th Congress of Asian Society of Cardiovascular Imaging
Hong Kong, China

June 22-25
CARS 2011 - Computer Assisted Radiology and Surgery - 25th International Congress and Exhibition Berlin, Germany

June 27-July 1
NYU Summer Radiology Symposium at The Sagamore
Lake George, NY, United States

July 18-22
Clinical Case-Based Radiology Update in Iceland
Reykjavik, Iceland

August 1-5
NYU Clinical Imaging Symposium in Santa Fe
Santa Fe, NM, United States

September 22-25
European Society of Neuroradiology (ESNR) XXXV Congress and 19th Advanced Course
Antwerp, Belgium

October 12-14
International Conference Vipimage 2011 - Computational Vision and Medical Image Processing
Algarve, Portugal

October 15-16
Essentials of Emergency and Trauma Radiology
Ottawa, Canada

October 23-29
2011 IEEE NSS - 2011 IEEE Nuclear Science Symposium and Medical Imaging Conference
Valencia, Spain

October 25-28
NYU Radiology in Scottsdale - Fall Radiology Symposium in Scottsdale
Scottsdale, AZ,
United States

October 28-30
Fourth National Congress of Professionals of Radiological Techniques Florianópolis, Brazil

October 28-30
Multi-Modality Gynecological & Obstetric Imaging
Ottawa, Canada

November 3-4
9th ESGAR Liver Imaging Workshop
Taormina, Italy

November 15-19
EANM 2011 - Annual Congress of the European Association of Nuclear Medicine
Birmingham,
United Kingdom

November 22-29
NSS/MIC - Nuclear Science Symposium and Medical Imaging Conference 2011 Valencia, Spain

November 26-28
8th Asia Oceaninan Congress of Neuro-Radiology Bangkok,
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INSTRUCTIONS TO AUTHORS

GENERAL INFORMATION

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Columns

The columns in the issues of *WJR* will include: (1) Editorial: To introduce and comment on major advances and developments in the field; (2) Frontier: To review representative achievements, comment on the state of current research, and propose directions for future research; (3) Topic Highlight: This column consists of three formats, including (A) 10 invited review articles on a hot topic, (B) a commentary on common issues of this hot topic, and (C) a commentary on the 10 individual articles; (4) Observation: To update the development of old and new questions, highlight unsolved problems, and provide strategies on how to solve the questions; (5) Guidelines for Basic Research: To provide guidelines for basic research; (6) Guidelines for Clinical Practice: To provide guidelines for clinical diagnosis and treatment; (7) Review: To review systemically progress and unresolved problems in the field, comment on the state of current research, and make suggestions for future work; (8) Original Articles: To report innovative and original findings in radiology; (9) Brief Articles: To briefly report the novel and innovative findings in radiology; (10) Case Report: To report a rare or typical case; (11) Letters to the Editor: To discuss and make reply to the contributions published in *WJR*, or to introduce and comment on a controversial issue of general interest; (12) Book Reviews: To introduce and comment on quality monographs of radiology; and (13) Guidelines: To introduce consensuses and guidelines reached by international and national academic authorities worldwide on the research in radiology.

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There are unstructured abstracts (no more than 256 words) and structured abstracts (no more than 480). The specific requirements for structured abstracts are as follows:

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Key words

Please list 5-10 key words, selected mainly from *Index Medicus*, which reflect the content of the study.

Text

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Figures should be numbered as 1, 2, 3, *etc.*, and mentioned clearly in the main text. Provide a brief title for each figure on a separate page. Detailed legends should not be provided under the figures. This part should be added into the text where the figures are applicable. Figures should be either Photoshop or Illustrator files (in tiff, eps, jpeg formats) at high-resolution. Examples can be found at: http://www.wjgnet.com/1007-9327/13/4520.pdf; http://www.wjgnet.com/1007-9327/13/4554.pdf; http://www.wjgnet.com/1007-9327/13/4891.pdf; http://www.wjgnet.com/1007-9327/13/4986.pdf; http://www.wjgnet.com/1007-9327/13/4498.pdf. Keeping all elements compiled is necessary in line-art image. Scale bars should be used rather than magnification factors, with the length of the bar defined in the legend rather than on the bar itself. File names should identify the figure and panel. Avoid layering type directly over shaded or textured areas. Please use uniform legends for the same subjects. For example: Figure 1 Pathological changes in atrophic gastritis after treatment. A: ...; B: ...; C: ...; D: ...; E: ...; F: ...; G: …*etc*. It is our principle to publish high resolution-figures for the printed and E-versions.

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Acknowledgments

Brief acknowledgments of persons who have made genuine contributions to the manuscript and who endorse the data and conclusions should be included. Authors are responsible for obtaining written permission to use any copyrighted text and/or illustrations.

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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/index.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).

Units

Use SI units. For example: body mass, m (B) = 78 kg; blood pressure, p (B) = 16.2/12.3 kPa; incubation time, t (incubation) = 96 h, blood glucose concentration, c (glucose) 6.4 ± 2.1 mmol/L; blood CEA mass concentration, p (CEA) = 8.6 24.5 μg/L; CO_2 volume fraction, 50 mL/L CO_2, not 5% CO_2; likewise for 40 g/L formaldehyde, not 10% formalin; and mass fraction, 8 ng/g, *etc.* Arabic numerals such as 23, 243, 641 should be read 23 243 641.

The format for how to accurately write common units and quantums can be found at: http://www.wjgnet.com/1949-8470/g_info_20100313185816.htm.

Abbreviations

Standard abbreviations should be defined in the abstract and on first mention in the text. In general, terms should not be abbreviated unless they are used repeatedly and the abbreviation is helpful to the reader. Permissible abbreviations are listed in Units, Symbols and Abbreviations: A Guide for Biological and Medical Editors and Authors (Ed. Baron DN, 1988) published by The Royal Society of Medicine, London. Certain commonly used abbreviations, such as DNA, RNA, HIV, LD50, PCR, HBV, ECG, WBC, RBC, CT, ESR, CSF, IgG, ELISA, PBS, ATP, EDTA, mAb, can be used directly without further explanation.

Italics

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

Genotypes: *gyrA*, *arg* 1, *c myc*, *c fos*, *etc.*

Restriction enzymes: *Eco*RI, *Hin*dI, *Bam*HI, *Kbo* I, *Kpn* I, *etc.*

Biology: *H. pylori*, *E coli*, *etc.*

Examples for paper writing

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Frontier: http://www.wjgnet.com/1949-8470/g_info_20100313182448.htm

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