Pictorial Essay

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대한영상의학회지

Usefulness of Virtual Fluoroscopy in Emergency Interventional Radiology

응급 인터벤션 영상의학에서 가상 투시영상 검사의 유용성

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Interventional radiology (IR) embolization requires image guidance to steer catheters to the site of bleeding, where embolic agents such as Gelfoam or coils are administered to stem blood flow. In addition to treating iatrogenic trauma, embolization is suitable for injuries precluding surgery such as blush-bleeding of the liver or kidney and for locating and treating intimal blood vessel tears. However, during hospital off-hours (such as nights and holidays), experienced IR personnel are not always available. In such situations, there is a dire need to build a coordinated IR team to treat seriously injured patients rapidly and reliably. This article reviews the current principles and techniques used in IR such as virtual fluoroscopy and their usefulness, and makes a convincing case for emergency IR.

Index terms Emergency; Interventional Radiology; Computed Tomography, X-Ray

INTRODUCTION

Emergency departments of hospitals constantly face situations requiring emergency interventional radiology (IR). These situations include active bleeding due to organ, bone, and soft tissue trauma; coughing out blood; blood vessel embolism; tumor rupture; percutaneous abscess; and biliary system drainage. Normally, conditions such as shock, disseminated intravascular coagulation, and sepsis require rapid intervention to save the patient's life. However, during hospital off-hours (such as nights and holidays), experienced IR personnel are not always available. In these situations, a well-functioning coordinated IR team is required to treat seriously injured patients rapidly and reliably. Thus, emergency departments must build a collaborative team capable of performing quick and safe IR at any time on a daily basis. Preoperative planning for IR using CT and virtual fluoroscopy facilitates a safer, more reliable, and shorter procedure with fewer complications.

In this perspective review, we report the effectiveness of virtual fluoroscopy in IR at our hospital.

We used virtual fluoroscopic preprocedural planning (VFPP) in IR as a new navigation system. VFPP is a navigation system in which trace lines between the blood vessel and target lesions are constructed along the target blood vessel with a ray summation image, as in fluoroscopy. The trace line depicted on the 3D image of the whole body is used as a reference for selecting the responsible vessels during forceps handling (Fig. 1). VFPP is relatively easy as it uses power volume data from multi-slice CT analyzed on a workstation. Thus, because pre-acquired CT volume data are used, there is no need to purchase new and expensive IR devices. Herein, we report the feasibility of using VFPP for vessels in the manner explained above. To the best of our knowledge, such a report has not been previously published.

CREATING A VIRTUAL FLUOROSCOPIC IMAGE (TRAUMA CASE)

Volume data obtained from a CT workstation are used to trace out the blood vessels and create the virtual fluoroscopic image (Fig. 2). Production time is about 5 minutes using VINCENT (Ver. 4.4, Fujifilm Corp., Tokyo, Japan).

① Open 3D CT volume data.

② Trace out an appropriate path.

③ Invert the image with respect to black and white and apply the high edge of the 2D filter.

④ Rotate to various angles (a range of -30 to 30 degrees at intervals of 4 degrees totaling 13 images) and select a preoperative working angle (one without overlapping branches).

Production time is about 5 minutes.

Fig. 1. Virtual fluoroscopic image.
In the virtual fluoroscopic image, the position where extravasation is recognized by CT is circled, and the course of the responsible blood vessel towards the extravasation is indicated by a path (white line). The path begins at the superior mesenteric artery, marked with an asterisk (*). The image is very similar to that of an actual blood vessel; therefore, the catheter can be operated using the branch portion of the arrows (blue, yellow) as a guide.

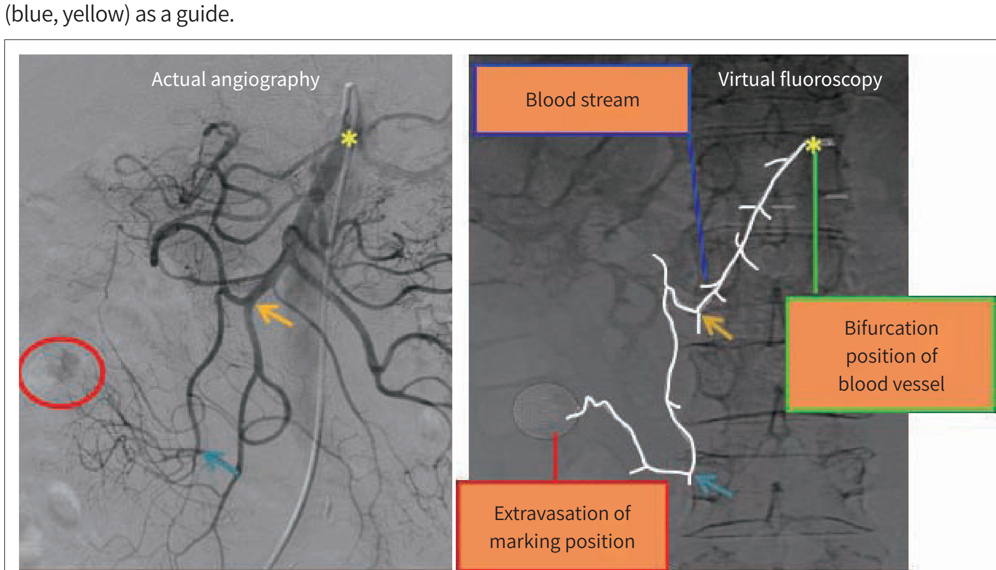
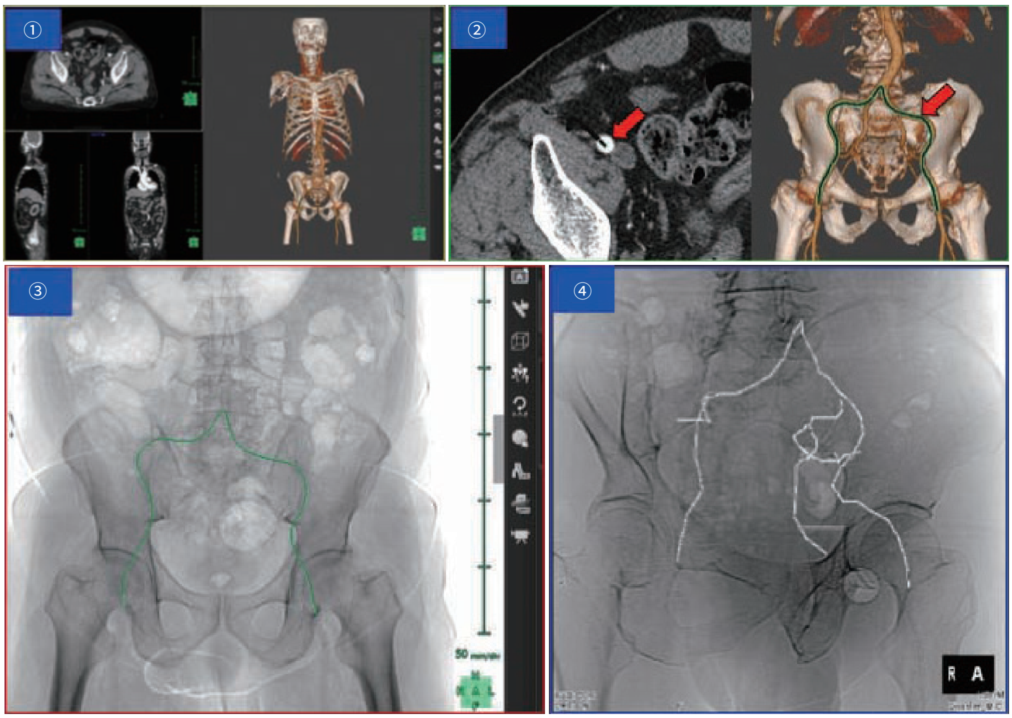


Fig. 2. A 52-year-old man in a major traffic accident.
Virtual fluoroscopic preprocedural planning is followed: 1 = open 3D CT volume data; 2 = trace out an appropriate path (arrows); 3 = invert the image with respect to black and white and apply the high edge of the 2D filter; 4 = rotate to various angles (a range of -30 to 30 degrees at intervals of 4 degrees totaling 13 images) and select a preoperative working angle (one without overlapping branches). Production time is about 5 minutes.



PROCEDURE DETAILS AND FINDINGS

PELVIC FRACTURE (Fig. 3)

Embolization is a useful, established, endovascular technique used in the emergency treatment of many traumatic injuries (1). Patients with coagulopathy and traumatic hemorrhagic shock arising from unstable pelvic ring injuries are significantly more prone to post-injury mortality, and consequently, rapid vascular embolization is indicated to prevent hemorrhagic shock in these patients (2). The process begins by tracing out the blood vessels of the common iliac artery and internal iliac artery to create an IR plan that uses virtual fluoroscopy. By rotating the virtual fluoroscopic image to an arbitrary angle, a view of the branch of the target blood vessel is easily obtained. Since the virtual fluoroscopic image is in 3D and can be rotated to an arbitrary angle, it is possible to visualize the angle at which IR can be most easily performed even before the operation and thus reduce the time required to grasp the anatomy during angiography, the amount of contrast medium and exposure required to view the vessels, and possibility of complications arising by shortening the time required for the procedure.

RENAL INJURY (Fig. 4)

The importance of angiography and selective renal embolization for treating renal trauma is increasing. Embolization is an alternative treatment to laparotomy in patients who do not

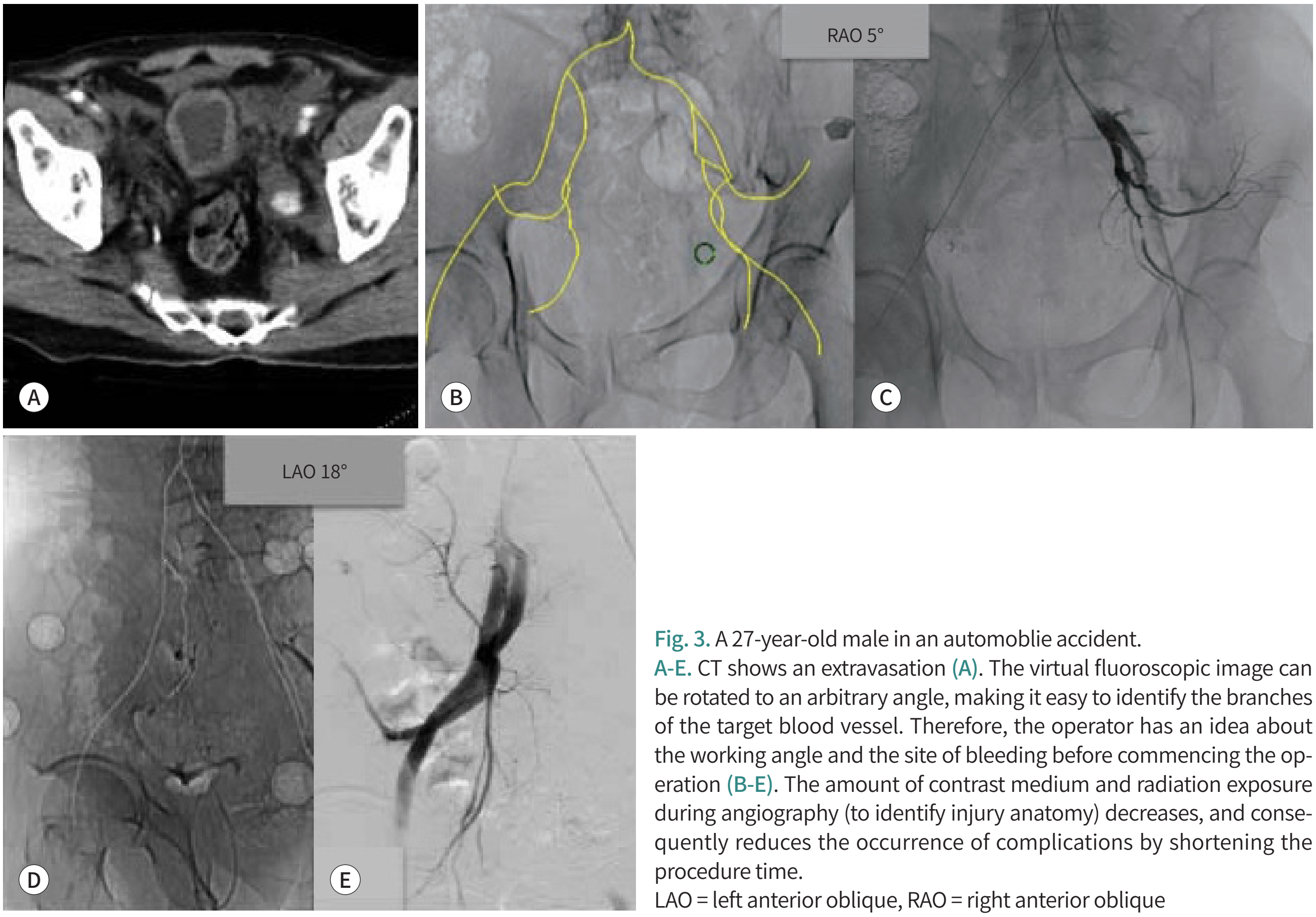
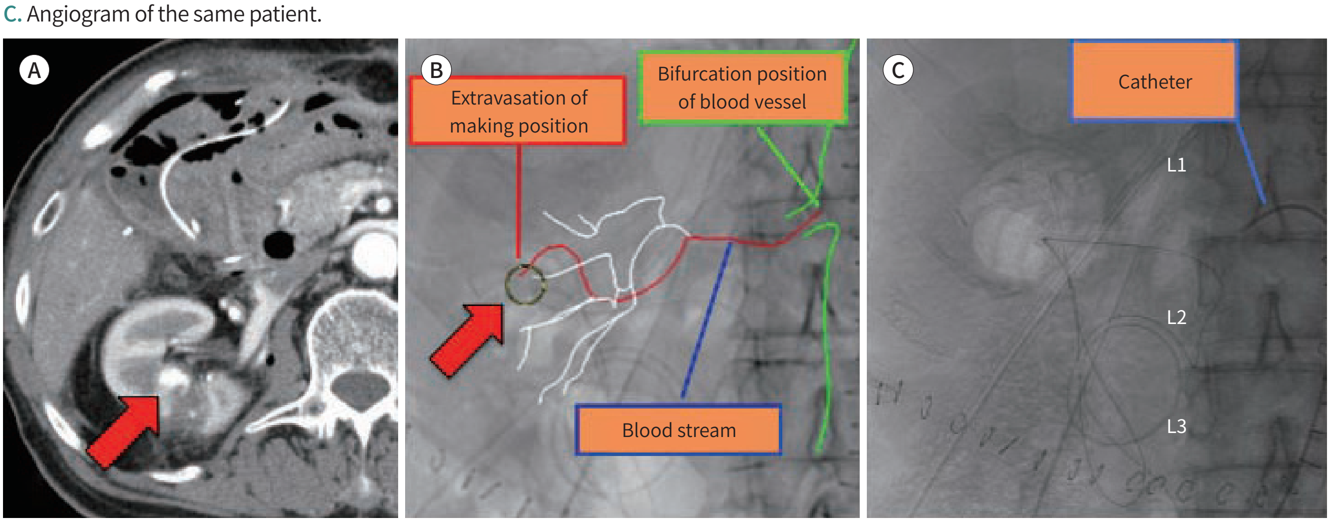


Fig. 3. A 27-year-old male in an automoblie accident.
A-E. CT shows an extravasation (A). The virtual fluoroscopic image can be rotated to an arbitrary angle, making it easy to identify the branches of the target blood vessel. Therefore, the operator has an idea about the working angle and the site of bleeding before commencing the operation (B-E). The amount of contrast medium and radiation exposure during angiography (to identify injury anatomy) decreases, and consequently reduces the occurrence of complications by shortening the procedure time.
LAO = left anterior oblique, RAO = right anterior oblique

Fig. 4. A 33- year-old man with renal injury after a high-velocity trauma.
A. CT shows extravasation from the lower pole of the right kidney into the abdominal cavity (arrow).
B. A virtual fluoroscopic image is created simultaneous with angiography. Identification of the extravasation from the right renal artery and the responsible branch. We quickly selected the responsible branches and confirmed hemostasis 15 minutes after beginning the procedure. Pseudoaneurysm formation in a Grade 4 injury (arrow).
C. Angiogram of the same patient.



require immediate surgery (3). Hemostasis with renal embolization was shown to be successful for grade 4 injuries of both the blunt and deep/penetrating types. A 94.4% success rate was reported in select patients with grade 4 or 5 blunt renal artery trauma (4). Moreover, it was found to reduce renal parenchymal injury and other complications when compared with surgical options (5). In this case, CT showed extravasation from the lower pole of the right kidney into the abdominal cavity, due to which the patient was immediately moved to the angiography room. A virtual fluoroscopic image was created simultaneously. Thereafter, we obtained the path of the right renal artery, quickly selected the responsible branches, and confirmed hemostasis 15 minutes after beginning the procedure.

BRONCHIAL ARTERY EMBOLIZATION (Fig. 5)

Rémy et al. first described bronchial artery embolization (BAE) in detail for control of hemoptysis in 1974 (6). Since then, BAE has evolved in terms of indications, technique, and efficacy. BAE is used for the treatment of both benign and malignant causes of hemoptysis as well as for all grades of hemoptysis (7-9). Using the BAE technique, super-selective catheterization of abnormal arteries using microcatheters is routinely performed. Previously, four studies have reported super-selective embolization (10-13). Super-selective catheterization enables bypassing of anterior spinal arteries and catheterization of smaller, more distal, and torturous arteries; thereby providing better overall hemoptysis control with lower risk of complications (14-17). However, at the same time, the degree of difficulty in handling the catheter increases. Virtual fluoroscopy is useful in cases where it is necessary to select many blood vessels in one procedure, such as for multiple injuries and BAE.

RUPTURE OF HEPATOCELLULAR CARCINOMA (Fig. 6)

Spontaneous hepatocellular carcinoma (HCC) rupture is a life-threatening complication that can be fatal. It has an incidence of 3–15% in the eastern countries; however, it is a rare

Fig. 5. A 52-year-old woman with a history of pulmonary sarcoidosis complaining of multiple episodes of hemoptysis in the previous 24 hours.
A-C. Virtual fluoroscopy is useful in cases where it is necessary to select many blood vessels in one procedure, such as in multiple injuries or bronchial artery embolization. For example, if selection is shortened by 3 minutes per blood vessel, a procedure selecting 10 blood vessels is shortened by 30 minutes. Left bronchial artery (green point), right bronchial artery (red point), posterior intercostal artery (yellow point).

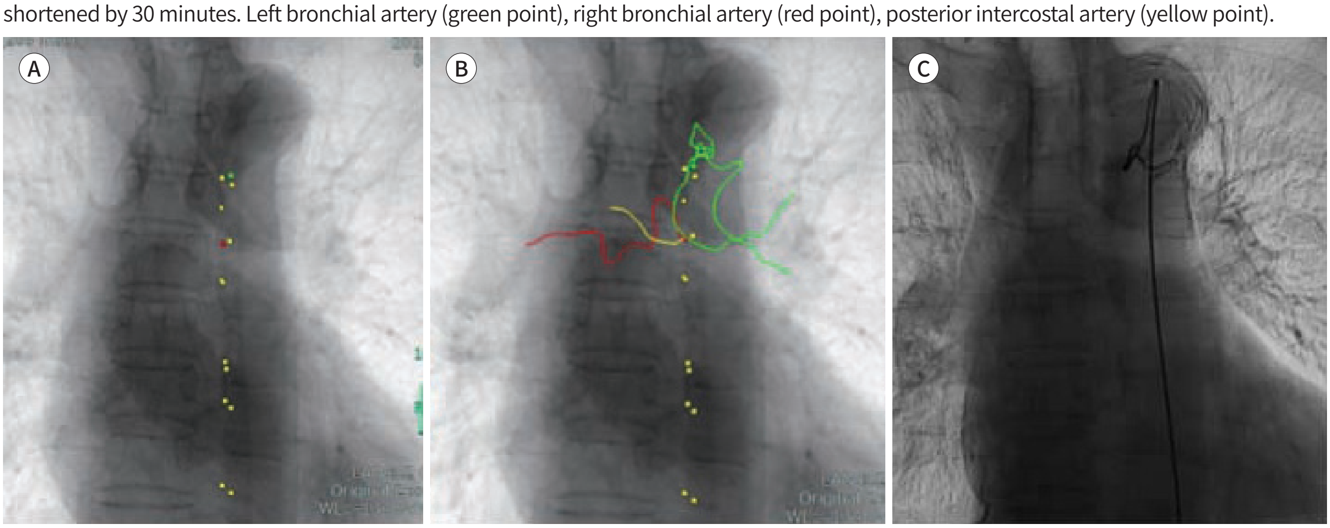
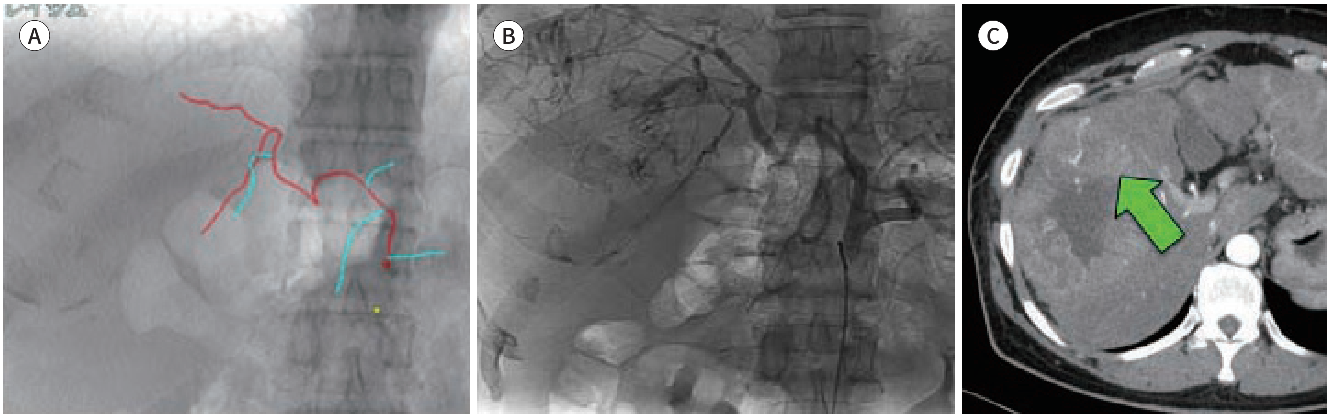


Fig. 6. A 68-year-old non-diabetic, non-alcoholic male patient with a dull aching pain in the right upper part of the abdomen.
A. The hepatic artery and its branches (red color) and its adjacent branching arteries (blue color) are reconstructed in the radiograph.
B. Celiac angiogram shows hepatic arteries and adjacent arteries, which are well correlated with reconstructed vessels in A.
C. Enhanced CT scan shows tumor enhancement (arrow) well correlated with tumor staining in B.



event in western countries (18). HCC rupture may be attributed to increased intra-tumoral pressure, occlusion of blood vessels by the tumor thrombus, rapid growth of the tumor, and necrosis. HCC rupture is a dangerous condition with a poor prognosis; the 30-d mortality ranges from 30% to 70% (19-21). In our cohort study, the 30-d mortality due to HCC rupture was 27.8% (22). Several investigators have concluded that transarterial embolization or surgery is an effective therapy for patients with HCC rupture (23, 24). Transarterial embolization is an effective and minimally invasive procedure and achieves immediate hemostasis. It is also the major procedure performed for patients with unresectable HCC.

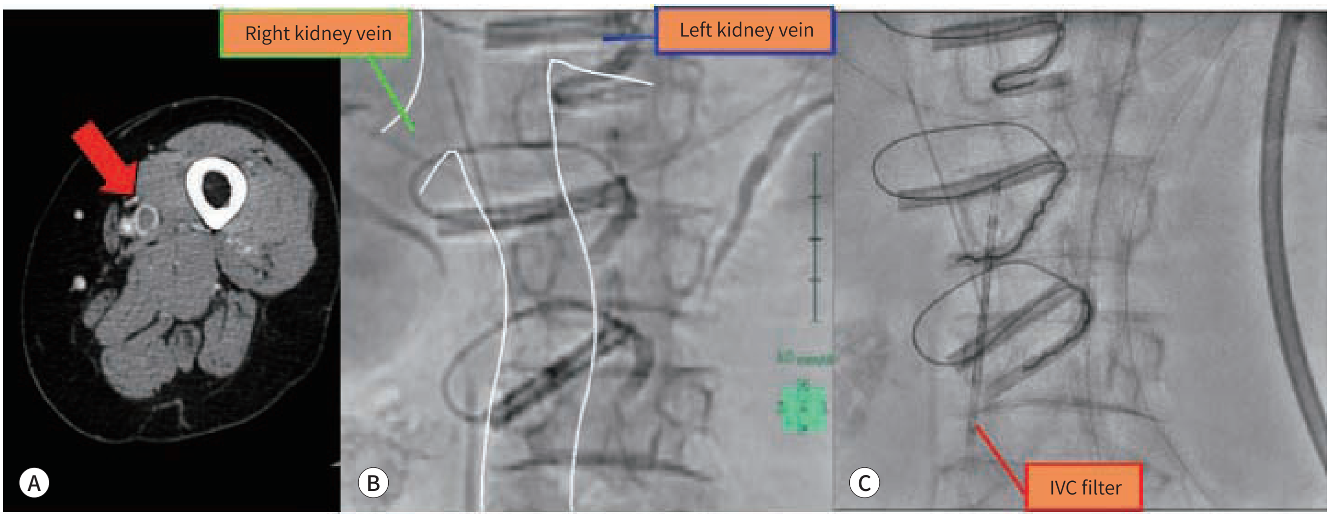
There are cases wherein the origin of the blood vessel is indicated only by a dot and the position of active bleeding is marked. While actively visualizing the affected blood vessels overlapped with the structure of the vertebral body, the diagnostic imaging team provides detailed instructions to the surgeon directing the tip of the catheter towards the target blood vessel. The surgeon can hence concentrate on controlling the catheter by watching only the fluoroscopic screen, and it becomes possible to select each blood vessel within seconds.

VIRTUAL FLUOROSCOPIC IMAGE FOR NON-VASCULAR IR

INFERIOR VENA CAVA FILTER FOR DEEP VEIN THROMBOSIS (Fig. 7)

Venous thromboembolism, manifesting as either deep vein thrombosis or pulmonary embolism, is common worldwide and in Japan. In 2011, the estimated annual incidence in Japan was 126 per 1000000 people (25). Inferior vena cava (IVC) filters provide an alternative for the prevention of pulmonary embolism when anticoagulation therapy fails or is contraindicated (26). The IVC can have unusual geometry with odd shapes and be oriented (along the long axis) away from the horizontal plane. However, in axial and coronal CT images, it is not intuitive to grasp the detention position. Thus, obtaining a virtual fluoroscopic image to visualize the IVC for selection and placement of IVC filters is recommended in such cases. From contrast CT volume data, a virtual fluoroscopic image of the anatomy around the perspective of the filter indwelling is created. The left and right renal veins are traced out and the IVC filter is placed as

Fig. 7. A 56-year-old man with pain in the left calf.
A-C. Deep vein thrombosis is noted (A, arrow). From contrast CT volume data, a virtual fluoroscopic image of the anatomy around the perspective of the filter indwelling is created. The left and right renal veins are traced out and the IVC filter is placed as a guide for indwelling just below the renal veins (B, C). The virtual fluoroscopic image provides intuitive information about the position of the branches of the renal vein and spine necessary for catheter operation while avoiding the use of contrast medium for mapping the anatomy. Therefore, radiation exposure is reduced and complications are prevented because of the useful preoperative and intraoperative image support available.
IVC = inferior vena cava



a guide for indwelling just below the renal veins. The virtual fluoroscopic image provides intuitive information about the position of the branches of the renal vein and spine necessary for catheter operation while avoiding the use of contrast medium for mapping the anatomy. Therefore, radiation exposure is reduced and complications are prevented because of the useful preoperative and intraoperative image support available.

PERCUTANEOUS TRANSHEPATIC BILIARY DRAINAGE (Fig. 8)

Percutaneous transhepatic biliary drainage (PTBD) is a valuable alternative to access the biliary system when endoscopic biliary drainage is impossible or infeasible. PTBD is performed in patients with jaundice with dilated bile ducts (BDs) (27, 28). Non-vascular IR with virtual fluoroscopy also is effective in this regard.

In this example case of PTBD, a running path from the intrahepatic BD to the common BD was traced out on the virtual fluoroscopic image, and the distal part of the duodenum was marked with a superposed circle. This procedure reduces the amount of contrast media required and lowers the chance of bacteremia. Using increased amounts of contrast media with repeated and careless imaging can increase the internal pressure of the biliary tract and promote bacteremia.

PERCUTANEOUS CHOLECYSTOSTOMY (Fig. 9)

Percutaneous cholecystostomy is a widely performed and established method for draining of the gallbladder. The primary aim of emergency percutaneous cholecystostomy is to establish drainage rather than definitive cholecystography in acute cholecystitis. The contour of the gallbladder is displayed on the ray summation image as a virtual fluoroscopy image. The cli-

Fig. 8. A 68-year-old man with bowel obstruction due to metastatic carcinoma.
A running path from the intrahepatic BD to the common BD was traced out on the virtual fluoroscopic image, and the distal part of the duodenum was marked with a superposed circle. The clinician can choose the appropriate angle for the relevant technique based on the image. At RAO 30°, we can see the pathway via the epigastric approach.
BD = bile duct, PTBD = percutaneous transhepatic biliary drainage, RAO = right anterior oblique

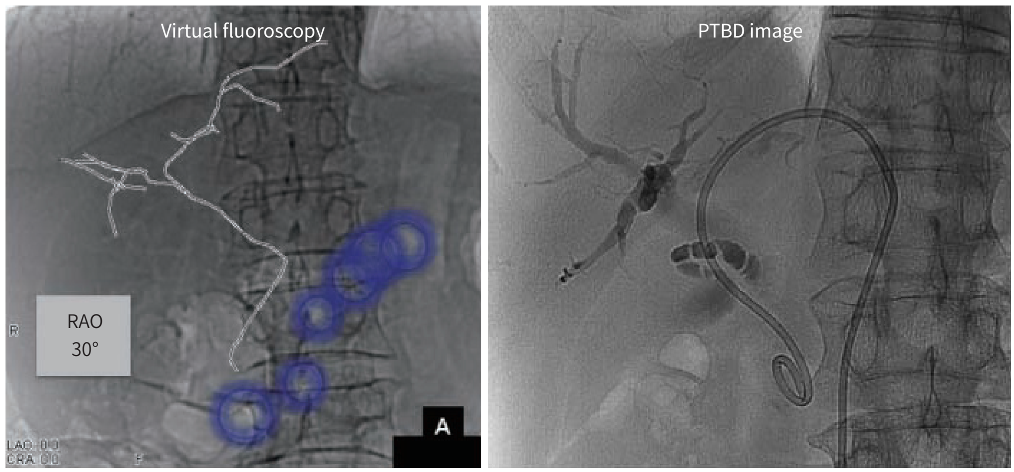
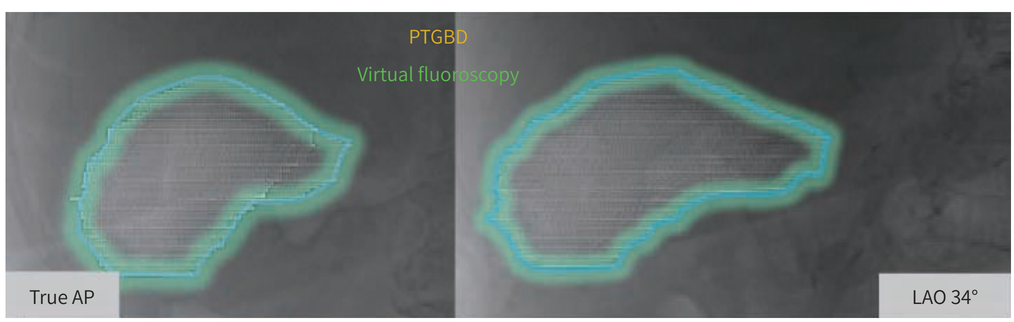


Fig. 9. A 78-year-old man with suspected cholecystitis.
The contour of the gallbladder is displayed on the ray summation image as a virtual fluoroscopy image. The clinician can choose the appropriate angle for the relevant technique based on the image. At LAO 34°, the gallbladder lumen is largest and the clinician can decide the approach.
AP = anterior-posterior, LAO = left anterior oblique, PTGBD = percutaneous transhepatic gallbladder drainage

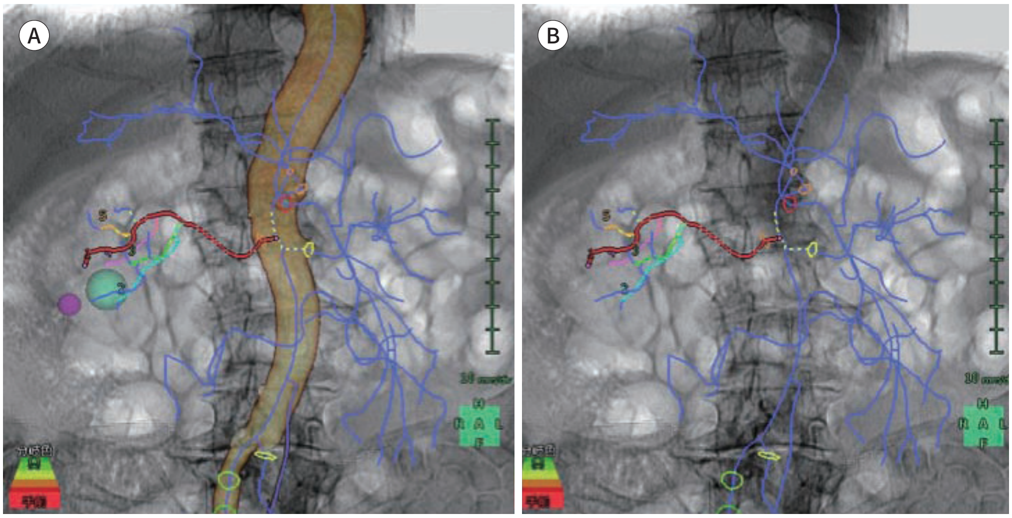


nician can choose the appropriate angle for the relevant technique based on the image. This method reduces the amount of contrast media required and lowers the chance of bacteremia. Furthermore, it reduces the chance of gall bladder perforation. Since the gall bladder wall is identified prior to operation, the guidewire can be handled cautiously. The gallbladder wall is usually necrotic in these patients and can be easily perforated with careless guidewire handling, resulting in serious complications such as bile peritonitis and abscess formation.

"IR SIMULATOR" MOUNTED IN VINCENT VER. 5 (Fig. 10)

Using an IR simulator, it is possible to automatically and semi-automatically extract the vascular region with high contrast, manually set the optimum X-ray tube angle (working angle) that can identify multiple nutrient vessels, and clearly observe the blood vessel to be embolized. Compared to using conventional angiography alone, the IR simulator requires low expo-

Fig. 10. A 43-year-old woman in a major traffic accident.
A, B. Image simulated nutrient blood vessel reaching right kidney injury from CT image of early arterial phase in “interventional radiology simulator” mounted in VINCENT ver.5.



sure, and the tip of the microcatheter can be advanced with just a small amount of contrast medium. In addition, it greatly shortens image creation time by automation and reduces the burden on radiologists and physicians, making it a helpful aid when there are limited personnel for emergencies during the night and on holidays.

CONCLUSIONS

Intraoperative referencing using virtual fluoroscopy in emergency IR is an intuitive and useful tool for better localization of the guidewire in blood vessels, thereby shortening X-ray fluoroscopy time and overall procedure time while minimizing radiation exposure and contrast medium use, and reducing complications. The substantial difference in using the 3D roadmap with the IR device is that there is no need to use contrast medium again during IR, and thus, no need for additional radiation exposure. Moreover, anyone can be easily trained to perform this procedure. Further, because pre-acquired CT volume data are used, it is not necessary to purchase new and expensive IR equipment. Hence, it is possible to perform virtual fluoroscopy assisted IR anytime and anywhere as long as there are CT devices and workstations in the facility. Furthermore, IR simulation, which is the latest application, drastically shortens the creation time of the virtual fluoroscopic image and makes it possible to reduce the burden on the image creator. This technology provides the possibility to lower costs and reduce interventional procedure time.

Author Contributions

Writing—original draft, all authors; and writing—review & editing, all authors.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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응급 인터벤션 영상의학에서 가상 투시영상 검사의 유용성

Yoshihiro Tanaka[1*] · Akitoshi Oosone[1] · Asuka Tsuchiya[2]

인터벤션 색전술은 영상 유도하에 카테터를 출혈 부위에 위치하고, 젤폼 또는 코일 등의 색전물질을 사용해서 출혈을 막는다. 의인성 외상을 치료하는 것 이외에, 수술이 불가능한 간 및 신장의 출혈(blush-bleeding) 및 혈관 손상을 진단하고 치료하는 데에 유용하다. 그러나 병원 일과 시간이 아닌 경우, 숙련된 인터벤션 의료팀이 항상 준비되어 있지는 않다. 이러한 상황에서 인터벤션 팀의 협업은 심각한 손상을 입은 환자를 빠르게 치료하는데 꼭 필요하다. 이 논문은 가상 투시장비 검사의 유용성에 대한 현재의 원칙과 기술을 검토하고 응급 인터벤션 시술에서 유용한 사례들을 제시하고자 한다.

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