Arterial Embolization for Controlling Life-threatening Traumatic Pelvic Hemorrhage

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Background/Purpose. To evaluate the effectiveness of transcatheter arterial embolization (TAE) for controlling arterial hemorrhage due to pelvic trauma.

Methods. In this retrospective study, we analyzed the surgical outcomes of 40 hemodynamically unstable patients who underwent pelvic angiography for traumatic pelvic hemorrhage during the period January 2004 to July 2007. TAE was performed when direct signs (eg, contrast extravasation and pseudoaneurysm) or indirect signs (eg, vasospasm and vessel tortuosity) of vascular injury were noted.

Results. Embolization was required in 36 (90%) patients. Indications included active contrast extravasation in 31 (86%) and indirect signs of vascular injury in 5 (13.9%). Repeated TAE for recurrent pelvic arterial hemorrhage during the same admission was necessary in 5 (13.9%) of the 36 patients. The success rate of embolization was 94.4%. All patients had been followed for at least 3 months. There were no complications directly associated with the embolization procedures during the follow-up period.

Conclusion. TAE is a safe and effective method for controlling life-threatening traumatic pelvic hemorrhage. **(Mid Taiwan J Med 2009;14:16-26)**

Key words

angiography, embolization, pelvic hemorrhage, pelvic trauma

INTRODUCTION

Blunt trauma to the pelvis is often the result of traffic accidents or falling from heights. The prevalence rate of pelvic or abdominal organ injuries in patients who sustain pelvic blunt trauma ranges from 11% to 20% [1,2]. Hemorrhage is very common in patients with pelvic fracture and the bleeding sources may be venous or arterial in origin. The mortality rate among patients with pelvic fracture who develop hemorrhagic shock ranges from 36% to 54% [3,4]. Pelvic hemorrhage usually occurs near bony fracture margins or arises from venous structures, and can normally be controlled after intravascular fluid resuscitation and adequate pelvic external fixation in most patients who sustain major trauma to the pelvis [5,6]. However, about 5% to 20% of patients with pelvic trauma present with life-threatening hemorrhage, which is most commonly caused by arterial bleeding [1,4]. Hypotension and contrast material extravasation seen on computed tomography (CT) images in the arterial phase are reliable indicators of arterial injury [3].

Pelvic packing is applied to initially control massive pelvic bleeding duc to significant venous injury or when the patient is sufficiently stabilized to tolerate transportation to the angiography suite [7,8].Other techniques to control bleeding due to vascular injuries associated with pelvic trauma

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include open surgical exploration, ligation of the iliac artery or vein, application of local hemostatic therapies, and transcatheter arterial embolization (TAE) [7-10]. TAE is an effective technique for facilitating rapid hemostasis at active arterial bleeding sites [11,12]. Approximately 3% of patients with pelvic fracture present with arterial injury requiring embolization [2,12,13]. The success rate of TAE ranges from 85% to 100%. The objective of this study is to evaluate the clinical effectiveness of TAE for the management of life threatening hemorrhage and to compare the outcome in our patients with that reported in the literature.

MATERIALS AND METHODS

Study population

We reviewed the medical records of all hemodynamically unstable patients with pelvic blunt trauma who underwent angiography during the period 2004 to July 2007. A patient was considered hemodynamically unstable if the initial systolic blood pressure was less than 90 mm Hg during the first 12 hours of admission. Data, including age, gender, the mechanism of injury, and the type of pelvic fracture were analyzed. Pelvic radiographs were reviewed by a bone radiologist and fractures were classified according to the Young and Burgess system [14]. Patients who had associated injuries in the abdominal region were excluded from the study.

Diagnostic imaging evaluation

The decision to perform CT or an angiography was made by the trauma surgeons after consultation with interventional radiologists, and was based on the degree of hemodynamic instability. The CT images were obtaind on a 16- channel multidetector CT scanner (GE Lightspeed; GE Medical Systems, Milwaukee, Wis) or on a traditional helical CT scanner (Picker PQ5000).

CT was routinely performed with intravenous contrast enhancement using 2 mL/kg (maximum, 100 mL) of iodine solution (300 mg/mL) injected at a rate of 3 mL/second through a power injector. Images from the lower chest to the pelvis were obtained with a collimation of 15 mm and a table speed of 15 mm/second. The scanning parameters of the 16- channel CT were as follows: pitch, 1.375, 120 kV, 110 mA (effective), and section thickness, 1.25 mm. The images were reconstructed with an effective section thickness of 5 mm. The transverse source images were transferred to two online workstations for the preparation of reconstructions.

Digital subtraction angiography (DSA) images were acquired by the GE- LCA angiographic system (GE Medical Systems, Milwaukee, Wis). All angiographic procedures were performed by one of three interventional radiologists, each of whom had at least 10 years of vascular radiology experience. Catheterization was performed through the right or left groin. A nonselective angiography of the lower abdominal aorta was performed, followed by a selective angiogram of the pelvic vessels. Arterial injury was diagnosed when contrast extravasation (Fig. 1 and Fig. 2), pseudoaneurysms, arteriovenous fistula, vasospasm or vessel tortuosity was present on the angiogram [15,16].

Management

When a bleeding site was identified on the pelvic angiogram, embolization was performed. Embolization agents included Gelfoam or steel coils or both. Coils were the preferred embolic agents for proximal focal vascular injuries and pseudoaneurysms, whereas multiple or distal arterial injuries were embolized using Gelfoam cubes. Superselective embolization of bleeding sites was preformed by placing coils next to the target sites. In hemodynamiclly unstable patients, vasospasm or tortuosity is frequently seen on angiograms and may obscure the source of arterial bleeding due to vasoconstriction [15,16]. Therefore, preemptive internal iliac artery embolization was performed in all hemodynamically unstable patients with evidence of hematoma in the pelvic cavity on CT images or with indirect signs of vascular abnormalities on angiographic images. The total maximum contrast load used for CT and angiography was 200 mL.

Post-embolization angiography was performed to evaluate hemostasis and collateral supply. External fixators were applied to the pelvis after the TAE procedure.

Emergency laparotomy was indicated for patients who became profoundly hypotensive (SBP < 60 mmHg) and did not respond to fluid resuscitation during CT or angiography.

Fig. 1. A: The axial arterial phase CT image shows extravasation of contrast material (arrow) within a hematoma in the pelvic cavity. B and C: Volume-rendered and Oblique coronal MIP images show multiple fractures of the pelvic ring with extravasation of contrast material (arrow) from left internal iliac artery in the ischiorectal fossa. D: Angiogram of left common iliac artery shows contrast extravasation (arrow) from left proximal internal iliac artery. Embolization with two 5 cm × 5 mm coils and a 4 cm × 3 mm coil was performed. E: The final superselective and gross control angiograms confirmed successful cessation of the hemorrhage.

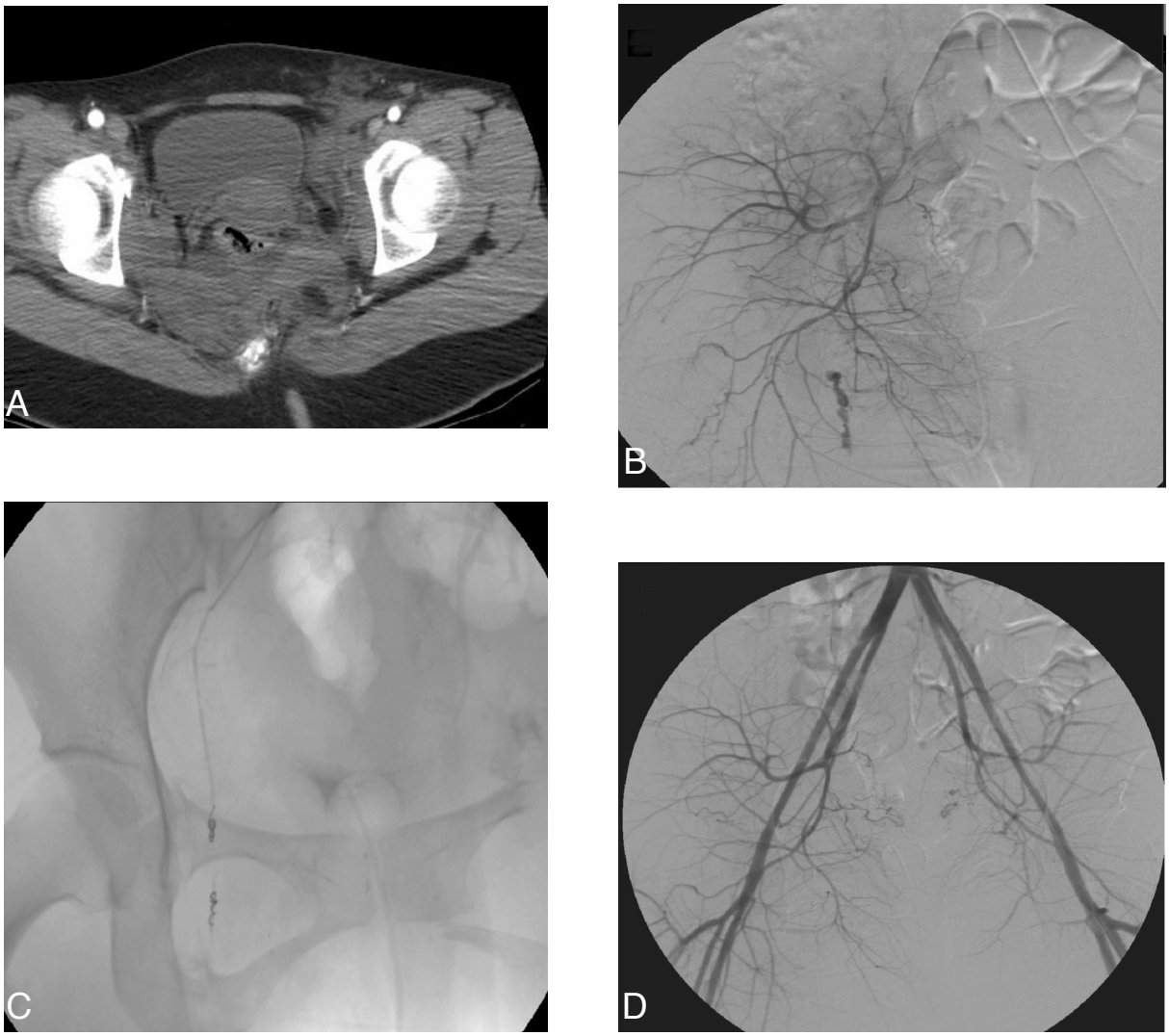

Fig. 2. A: The axial arterial phase CT image demonstrates pelvic fractures and hematoma without contrast extravasation in pelvic cavity. B: Conventional angiogram demonstrates continuous active hemorrhage from a branch of the right internal iliac artery. C: It was subsequently embolized by two coils and Geofoam. D: Post-embolization angiogram shows no evidence of contrast extravasation.

Embolization was considered successful when there was evidence of improvement in vasospasm and when there was no evidence of contrast extravasation (Fig. 1E) or pseudoaneurysm on the post-TAE pelvic angiogram, as well as when there was no evidence of hemorrhage on the repeat angiogram. Repeat angiography was indicated for patients who became hemodynamically unstable after the initial pelvic embolization. Recurrent hemorrhage was diagnosed when there was evidence of bleeding from a previously embolized vessel or collateral flow to the same site. A new bleeding site was diagnosed when there was evidence of extravasation or pseudoaneurysm that had not been identified in a previously studied artery.

The success rate of embolization and the mortality rate after successful embolization were recorded. The success rate of embolization was defined as the percentage of patients who did not require re-embolization at the previous embolization site during the same admission compared with the total number of patients with abnormal angiographic findings. The effectiveness of embolization was defined as the percentage of patients who did not have

radiographic or clinical evidence of bleeding after embolization compared with the total number of patients with abnormal angiographic findings. The safety of embolization was determined by the complications related to puncture site, contrast material administration, catheter insertion and advancement, and tissue necrosis after embolization of arteries supplying these tissues.

Follow-up

All patients were followed up for at least 3 months after the TAE procedure. The mortality rate and the complications related to the procedure were recorded.

RESULTS

Study population

During the period January 2004 to July 2007, a total of 78 hemodynamically unstable patients with pelvic blunt trauma and a systolic blood pressure of less than 90 mm Hg at presentation or within 12 hours of admission underwent angiography. Thirty-eight patients were excluded from this study because they had additional injuries in the abdominal region or because they were profoundly hypotensive (SBP < 60 mm Hg) and required emergency laparotomy. Therefore, the final study population comprised 40 patients (24 men, 16 women; mean age, 42.6 years; range, 17 to 70 years) who underwent pelvic angiographic examinations because of unstable blood pressure after fluid challenge. The causes of blunt pelvic trauma included falls from heights (N = 3) and vehicular accidents (N = 37). CT images were obtained using a 16-channal multidetector CT (MDCT) scan (Fig. 1) in 28 patients and using a spiral CT in 7 patients. Angiography without prior CT imaging was performed in 5 patients.

Types of pelvic fracture

All 40 patients undergoing pelvic angiographies had pelvic bone fractures. Radiographic pelvic fracture patterns were classified based on the Young-Burgess classification system (Table 1).

Angiography and TAE

The clinical information, angiographic findings, number of arterial embolization procedures, type of embolizer, associated organ injury and mortality in these 40 patients are summarized in Table 2. Arterial hemorrhage was initially diagnosed in 36 (90%) patients. Among them, active contrast extravasation was noted in 31 (86%) and more than 2 bleeding sites were noted in 25 (80.6%). Two pseudoaneurysms and one arteriovenous fistula were identified and successfully embolized in 3 patients.

Six patients (6/40, 15%) underwent repeated pelvic angiography for suspected recurrent pelvic arterial hemorrhage after the initial angiography (mean 2.1 days) during the same admission and 5 patients underwent repeated TAE. Among them, 3 new bleeding sites were embolized in 3 patients. Initial angiograms revealed no abnormalities in 4 patients; however arterial hemorrhage requiring embolization was noted on the second angiogram in 1 patient (Fig. 3); the other 3 patients were resuscitated by fluid challenge and medical treatment after the initial angiography.

CT

Of the 35 patients who underwent both CT and angiography, 28 had positive findings of contrast extravasation in the arterial phase on CT images. Among the 7 patients with no definite contrast extravasation in the arterial phase on CT images, initial angiography revealed abnormalities in 4 patients (Fig. 2).

Outcome and complication

The success rate of embolization was 94.4% (n = 34). The mortality rate was 13.9 % (n = 5). Three patients died after the initial TAE due to extra-pelvic organ injuries. The other 2 patients had multiple bleeding sites and died due to persistent hemodynamic instability. All patients were followed up for 4 to 18 months (mean, 13.7 months). There were no complications directly associated with the embolization procedures.

DISCUSSION

Arterial injury due to pelvic trauma usually involves the branches of the internal iliac artery, including the inferior gluteal, vesical, obturator,

Table 1. Types of pelvic fractures according to Young-Burgess classification correlated with findings of pelvic arterial bleeding (N = 40)

Fracture calcification	Characteristics	No. of patients	Positive findings in initial angiography (n = 36)	Bilateral internal iliac artery injury (n = 12)	More than 2 bleeding sites (n = 25)
APC-I	Pubic diastasis < 2.5 cm	7	4	0	1
APC-II	Pubic diastasis > 2.5 cm, anterior SI joint disruption	2	2	0	1
APC-III	Type II plus posterior SI joint disruption	2	2	1	2
LC-I	Ipsilateral sacral buckle fractures, ipsilateral horizontal pubic rami fractures (or disruption of symphysis with overlapping pubic bones)	4	3	0	1
LC-II	Type I plus ipsilateral iliac wing fracture or posterior SI joint disruption	6	6	0	3
LC-III	ipsilateral side across the midline to affect the contralateral hemipelvis	5	5	2	5
VS	Vertical pubic rami fractures, SI joint disruption +/– adjacent fractures	4	4	1	2
CM	involvement more than 1 pattern of injury	10	10	8	10

APC = anteroposterior compression; LC = lateral compression; VS = vertical shear; CM = combined mechanism; SI = sacroiliac.

Table 2. Clinical information, angiographic findings, and embolization in 40 patients with pelvic trauma

	No. of patients	Embolizer used
Arterial injury		
Active bleeding		
Bilateral internal iliac arteries	12	1G, 11G/C
Ipilateral internal iliac artery	17	6C, 11G/C
Internal and external iliac arteries	2	2G
Indirect sign	5	5G
Normal finding	4	0
Associated injuries		
Lung	7	
Brain	6	
Lower limbs	5	
Mortality		
Pelvic hemorrhage	2	
Multiple organ failure	2	
Intracranial hemorrhage	1	

G = gelfoam; C = coil, G/C = gelfoam and coil.

iliolumbar, and lateral sacral arteries [17]. TAE is a highly effective means of controlling hemorrhage from the internal iliac vessels and currently represents the definitive therapy for fracture-associated arterial hemorrhage [9,11,12,18]. The mortality rate among patients who undergo successful TAE ranges from 18% to 47% [12,19,20]. Although open surgical exploration for arterial bleeding in the pelvic cavity can directly access the iliac arteries so that the pelvic hematoma can be drained, this surgical approach may result in loss of tamponade, and hence, massive uncontrollable vascular bleeding [10]. TAE can stop arterial bleeding and allow the tamponade effect of the hematoma to control venous bleeding.

Because pelvic bleeding may be intermittent, embolization of bilateral internal iliac arteries is necessary in the presence of multiple sites of bleeding from bilateral internal iliac arteries or the presence of hemodynamic instability combined with unilateral or bilateral vascular abnormalities [21,22]. Embolic agents are selected based on the location and type of

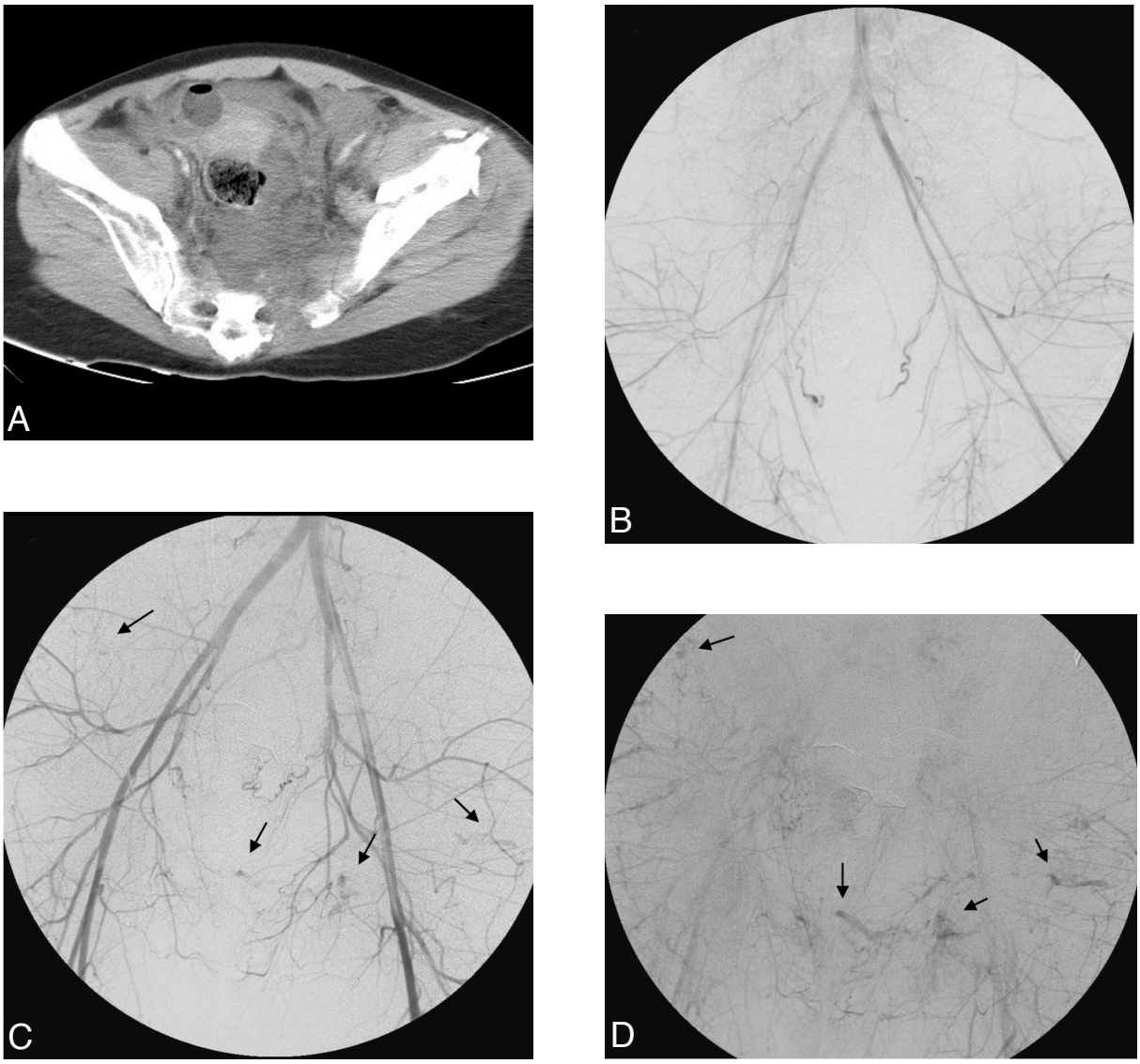

Fig. 3. A: The axial late arterial phase CT image demonstrates a large hematoma in the pelvic cavity. B: The conventional angiogram demonstrates small caliber bilateral internal iliac arteries without significant contrast extravasation. C and D: Two days later, angiogram shows multifocal contrast extravasation at peripheral branches of bilateral internal arteries (arrows) that were subsequently embolized by Gelfoam cubes.

arterial injury. Velmahos et al [16] reported that a gelatin sponge slurry can be used to temporarily embolize distal branches of the internal iliac arteries if massive bleeding is suspected. However, in the presence of coagulopathy caused by bleeding, it is possible that clots will not form easily in contact with the Gelfoam slurry and the vessel may recanalize before effective bleeding control is achieved.

After pelvic trauma, decreased erectile function has been reported in 40% of patients and urinary retention has been reported in 10% of patients [23,24]. Embolization of bilateral internal iliac arteries, however, usually does not compromise urogenital function, sexual function, pelvic floor function, or perineal skin integrity [15,25]. Based on our experience, no evidence of immediate injury, significant complications such as impotence, or skin necrosis was found after performing embolization of bilateral internal iliac arteries, indicating that the procedure is safe.

Contrast-enhanced CT images can identify

the site of contrast material extravasation in patients with arterial hemorrhage due to pelvic trauma [26,27] and, therefore, is increasingly used for initial diagnosis in pelvic injuries. Early identification of patients who might benefit from embolization can reduce blood loss, prevent late complications related to transfusion, and improve outcome [2]. In the present study, the site of contrast material extravasation seen on 16-channel MDCT images corresponds well to the site of bleeding seen during angiography (Fig. 1). This information can help us to direct the performance of more selective injections of contrast material into arteries that are at high risk for injury and to more rapidly perform TAE of abnormal arteries. Akiyoshi Hagiwara et al [20] reported that CT scanning was predictive of arterial injuries with active bleeding in 93% of cases, a rate much higher than that found in our study (80%). This discrepancy may be due to differences in the CT scanners and protocols used between the two studies. A large hematoma and no contrast extravasation in the pelvic cavity was seen on CT scans in 4 patients with pelvic fracture; however, initial angiograms revealed active arterial bleeding, indicating that a large hematoma in the pelvic cavity on CT images may be an indirect sign of active bleeding.

Recurrent pelvic arterial hemorrhage may occur after successful angiographic control of pelvic arterial hemorrhage even when no abnormalities are present on the initial angiogram. Gourlay et al [28] revealed that the presence of pre-hospital or emergency room hypotension, pubic symphysis disruption, a transfusion rate of more than 2 units per hour, and the presence of more than 2 pelvic arterial injuries on the initial angiogram are significant risk factors for recurrent pelvic arterial hemorrhage. The rate of repeated angiography in our study (6 of 40 patients; 15%) is higher than that reported in their study (31 of 556 patients; 5.6%). This may be attributed to the small study population in our study and to the fact that most patients presented with more than two pelvic arterial injuries.

The mortality rate after successful embolization in this study is lower than the mortality rate of 17.6% reported by Wong et al [19]. It is believed that additional embolizers and preemptive embolization of bilateral internal iliac arteries can decrease the mortality rate. The mortality rates associated with angiography and TAE after successful embolization are difficult to estimate. This is because most deaths in pelvic trauma cases are related to the associated injuries rather than to uncontrolled hypotension. In this study, most deaths were due to multiple organ dysfunction syndrome or severe head injury.

Most pelvic hemorrhages related to fractures are self-limiting and only 5% to 20% of patients have potentially life threatening arterial hemorrhage [1,4,29]. Previous reports have implicated specific fracture patterns indicative of major ligamentous disruption (MLD) as having an association with arterial injury [10,30,31]. Lateral compression fracture type III, anteroposterior compression types II and III, combined mechanisms and vertical shear patterns are considered indicative of MLD. In the present study, arterial hemorrhage was found during angiography in the patients who had MLD and in those with non-MLD patterns of pelvic fracture. Therefore, although it is difficult to predict pelvic arterial bleeding based on the pattern of pelvic fracture. MLD pattern pelvic fractures may indicate the need for repeated angiography.

Several limitations exist in this study. First, this is a retrospective study with a small subject pool. Second, the isolated effect of TAE on patients' physiological response was difficult to assess in some patients because several interventions were performed simultaneously. Third, the long term complications of bilateral internal iliac artery embolization were not analyzed in this study. Finally, our study suffers from selection bias because we excluded patients with hemorrhage of abdominal organs in order to avoid influencing the TAE results.

In conclusion, our study shows that TAE is a safe and effective method for controlling pelvic hemorrhage in patients with hemodynamic instability or multiple pelvic fractures.

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動脈栓塞控制威脅生命的外傷性骨盆腔出血

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背景/目的　動脈栓塞控制威脅生命的外傷性骨盆出血的分析。

方法　從2004年1月到2007年7月共3.5年的時間內，有40位血行動力不穩定的外傷性骨盆出血的病人接受血管攝影與栓塞治療。倘血管有受傷的直接徵象(例如：顯影劑外滲和假性動脈瘤)或間接徵象(例如：血管痙攣和扭曲)時，施行經動脈栓塞止血。

結果　共有36個(90%)病人需栓塞，其中有31位有顯影劑外滲，5位有血管受傷的間接徵象。五位病人(5/40，12.5%)因懷疑再次骨盆動脈再出血而行二次血管攝影且栓塞。栓塞的成功率爲94.4%。在栓塞後追蹤3個月以上並沒有直接與栓塞相關的併發症。

結論　動脈栓塞是控制有生命威脅的外傷性骨盆出血既安全又有效的方法。（**中台灣醫誌 2009;14:16-26**）

關鍵詞

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