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Effectiveness and safety of bilateral internal iliac artery ligation with pre-peritoneal pelvic packing for life-threatening pelvic trauma

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ABSTRACT

This study analyzed the outcomes of bilateral internal iliac artery (IIA) ligation with preperitoneal pelvic packing (PPP) in hemodynamically unstable patients with major pelvic fractures. All-cause mortality was examined, periprocedural safety for critical circumstances was reviewed, and iliac artery ligation-related complications of the postoperative phase were evaluated. A total of 20 patients who suffered substantially from severe pelvic trauma with hemodynamic instability and subsequently underwent bilateral IIA ligation with PPP between January 1, 2017, and December 31, 2021, were enrolled in the study. The median participant age was 60.5 years, and 65.0% were male. The median systolic blood pressure was 68.5 mmHg on arrival. Increased lactate level (median, 11.05 mmol/L) suggested that the patients were in shock distinctly due to hypovolemia. It took approximately 1 h to complete the ligation of bilateral IIA to accomplish hemostasis (median, 65.5 min). The iliac vein was injured during dissection in three cases. During the ICU stay (median, 17.5 days), acute kidney injury was identified in 13 patients, likely due to volume depletion. The median ventilator-free days was 13.5; six patients were confirmed with ventilator-associated pneumonia. Moreover, 12 patients were diagnosed with acute respiratory distress syndrome. There was one case in which the lower extremity artery was acutely occluded. Anatomic hemostasis was achieved in 18 patients. The two patients for which anatomic hemostasis failed became two mortality cases from preperitoneal hemorrhage. Our analysis showed that bilateral IIA ligation with PPP was effective as a lifesaving procedure in hemodynamically unstable patients with a major pelvic fracture in terms of mortality due to fracture-related exsanguination. Moreover, the incidence of periprocedural complications was considered tolerable, making the procedure worth a try, especially in austere and underdeveloped healthcare settings.

Introduction

Major pelvic fractures account for 9% of patients with blunt injury [1–8], and life-threatening hemodynamic instability is known to make up 4% of all cases [9–11]. Despite appropriate resuscitation, the overall mortality rate remains as high as 60%, predominantly due to hypovolemic shock followed by uncontrolled retroperitoneal hemorrhage with acidosis during the first 24 h following injury [12–16].

Relentless controversy remains over what may be the most appropriate management for unstable patients with pelvic fracture; nevertheless, pelvic binding, external fixation, preperitoneal pelvic packing, and angiographic embolization have all been considered as core features according to the Eastern Association for the Surgery of Trauma practice management guidelines [17].

Pelvic packing as a hemostatic method for uncontrolled pelvic bleeding was first reported by Logothetopulos in 1926 and subsequently modified into the preperitoneal approach by Pohlemann in 1995 [18,19]. Until recently, preperitoneal packing has been widely utilized with efficacy by trauma surgeons, orthopedic surgeons, and emergency physicians in operating theaters and emergency departments within a few minutes of the patient's arrival. This technique has been a very effective solution for venous hemorrhage, responsible for 85% of pelvic fracture-related bleeding. In contrast, 15% of arterial injuries require other means of hemostasis, largely internal iliac artery embolization with angiography.

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However, in austere locations such as suburban, rural provinces of developing countries or military conflict combat zone, it may not be possible to facilitate interventional modalities in time due to a lack of treatment resources and personnel. Bilateral internal iliac artery ligation is thus beneficial and worth a try in such an unfavorable scenario.

This study analyzed the outcomes of bilateral internal iliac artery ligation with preperitoneal pelvic packing in hemodynamically unstable patients with major pelvic fractures. All-cause mortality was examined; periprocedural safety in critical circumstances and iliac artery ligation-related complications of the postoperative phase was evaluated.

The study was approved by the Institutional Review Board of the hospital (2022–03–018), which waived the requirement for informed consent.

Materials and methods

Study design and population

This retrospective observational study was based on the data obtained from the registry of a single regional trauma center that is responsible for one of 17 regions of Korea. Between January 1, 2017, and December 31, 2021, 408 patients over 18 years of age suffering from pelvic fractures with ISS 15 or higher were admitted to our center. Initially, 103 patients were hemodynamically unstable with systolic blood pressure below 90 mmHg on arrival. We routinely applied fluid resuscitation with blood products transfusion and pelvic binding; nevertheless, 39 patients showed no response. Hence, we performed pre-peritoneal pelvic packing immediately in the emergency department. Definitive surgery proceeded after transferring the patients to the operating room. Among them, one patient expired during the packing procedure just after arrival at the emergency department, 18 patients underwent packing solely, and 20 patients underwent bilateral internal iliac artery ligation with packing.

Furthermore, 369 patients were hemodynamically stable and/or responded to the fluid resuscitation. We progressed the whole body scan with CT angiography. In accordance with the result, 38 patients presenting extravasation on CT scan underwent embolization, and the other 331 patients were admitted to the intensive care unit for general management with or without scheduled fixation. A schematic flowchart that shows the resuscitation steps of our center for pelvic fracture and patient enrollment for each stage is presented in Fig. 1.

Preperitoneal pelvic packing and bilateral internal iliac artery ligation procedures

After draping aseptically with povidone-iodine, a midline incision, including the linea alba, was made from the umbilicus to the symphysis pubis with the scalpel blade avoiding puncture of the peritoneal cavity. The preperitoneal space had already been dissected with hematoma facilitating exploration. X-ray-detectable surgical sponges or abdominal pads were placed within the space between the peritoneum and pelvic ring. After packing, we placed a reusable surgical drape on the wound, tightened the pelvic binder (Arrow® T-POD™), and promptly transferred the patients to the operating theater. Under general anesthesia, we again explored the preperitoneal space, removing the packing materials individually. Additional surgical dissection was preferred superiorly to the arcuate line and posteriorly to the sacroiliac joint. Iliac vessels were easily found at the corner where the lateral border of the rectus abdominis muscle and arcuate line meet. Extreme caution was required in the dissection of the iliac artery from the adjacent iliac vein. We identified and clamped the internal iliac artery with a vessel loop (Fig. 2) and palpated the ipsilateral femoral artery pulsation in the inguinal area to confirm that the internal iliac artery had indeed been selected. The procedure was completed by ligating the bilateral internal iliac arteries using silk 3–0 twice, within cm of the iliac artery bifurcation. Routinely, temporary abdominal closure with negative pressure wound therapy was applied at the end of the procedure.

Table 1
Baseline patient characteristics.

Variables	Patients with bilateral IIA ligation (n = 20)	
Age, years	60.5	(31–88)
Male sex	13	(65.0%)
MOI		
Fall down	2	(10.0%)
Pedestrian accident	12	(60.0%)
Motor vehicle accident	4	(20.0%)
Crush injury	2	(10.0%)
Premedical history		
Hypertension	4	(20.0%)
Diabetes	1	(5.0%)
Cardiovascular disease	1	(5.0%)
Cerebrovascular accident	1	(5.0%)
Dyslipidemia	1	(5.0%)
Tuberculosis	1	(5.0%)
Chronic liver disease	0	(0.0%)
Chronic kidney disease	1	(5.0%)
Malignancy	2	(10.0%)
Previous medication		
Anticoagulation use	1	(5.0%)
Antiplatelet use	2	(10.0%)

Data are presented as the number (%) or the median.
MOI, mechanism of injury.

Definitions and outcomes

Baseline demographics and clinical characteristics were verified by reviewing electrical medical records. Patients with systolic blood pressure below 90 mmHg were hemodynamically unstable at admission [20]. Time to hemostasis was defined as the time interval between arrival at the emergency department and completion of ligation. Anatomic hemostasis was regarded to be achieved if no further unexpected hemostatic invasive procedures were anticipated after initial packing and ligation. The internal iliac vein injury was confined to the incidents that occurred during the dissection of the iliac vessels. Categorical variables are described as frequencies and percentages, and continuous variables are presented as medians and ranges.

Results

In total, 20 patients with pelvic fractures who had received preperitoneal pelvic packing and bilateral internal iliac artery ligation between January 2017 and December 2021 were identified and enrolled in the study. The median age of the group was 60.5 years, and 65.0% were male. A pedestrian traffic accident was the predominant mechanism of injury at 60.0%. One patient was hit by a falling steel sheet in a plant, and the other was buried under a collapsed log in the crush injury group (Table 1).

The median systolic blood pressure was 68.5 mmHg on arrival. Moreover, increased lactate (median, 11.05 mmol/L) and low hemoglobin levels (median, 7.0 g/dl) suggested that the patients were in shock distinctly due to hypovolemia. The adjacent abdominal injury was combined most frequently (90.0%), followed by traumatic brain injury (75.0%) with a low Glasgow coma scale (median, 6.5). The injury severity score was elevated (median, 42), corresponding to severe trauma (Table 2).

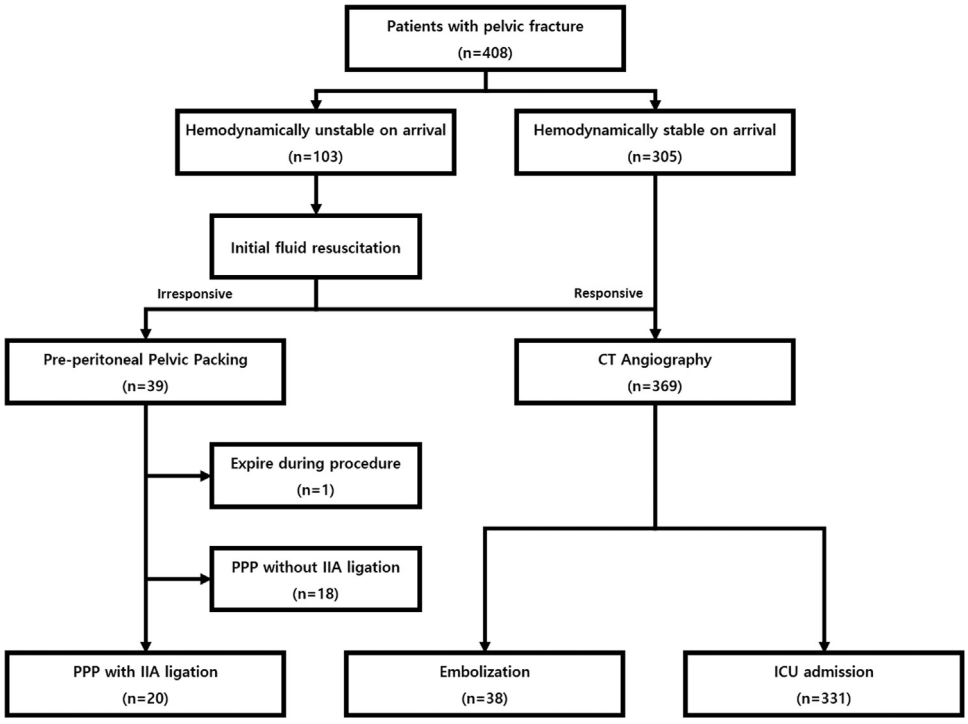

Fig. 1. Flow chart of the resuscitation steps and patient enrollment for each stage.

Table 2
Initial laboratory values and signs on admission.

Variables	Patients with bilateral IIA ligation (n = 20)	
Initial vital sign		
Initial SBP, mmHg	68.5	(31–86)
Initial HR, bpm	91.5	(53–138)
Initial laboratory studies		
Hb, g/dℓ	7.0	(4.1–9.8)
pH	7.005	(6.80–7.31)
Lactate, mmol/L	11.05	(5.60–15.0)
Concomitant injury		
Head & Neck	15	(75.0%)
Face	3	(15.0%)
Thorax	10	(50.0%)
Abdomen	18	(90.0%)
ISS	42	(29–66)
GCS	6.5	(3–15)

Data are presented as the number (%) or the median.
SBP, systolic blood pressure; HR, heart rate; Hb, hemoglobin; ISS, injury severity score; GCS, Glasgow coma scale.

Table 3
Coagulopathy and Transfusion within 24 h of admission.

Variables	Patients with bilateral IIA ligation (n = 20)	
INR	1.86	(1.25–8)
aPTT sec	66.8	(34.7–120)
pRBC, unit	28	(8–139)
FFP, unit	19.5	(3–114)
PC, unit	15.5	(0–48)
Cryoprecipitate, unit	10	(0–45)

Data are presented as the number (%) or the median.
INR, International Normalized Ratio; aPTT, Activated Partial Thromboplastin Time; pRBC, Packed Red Blood Cells; FFP, Fresh Frozen Plasma; PC, Platelet concentrates;.

Coagulopathy was evaluated initially with INR and aPTT. The number of units of each blood product for transfusion within the first 24 h of admission is presented in Table 3. Prolonged INR (median, 1.86) and increased aPTT (median, 66.8) indicated that the patients were under trauma-associated coagulopathy. Thus, massive transfusion of each blood product was unavoidable.

It took approximately 1 h to complete the ligation of the bilateral internal iliac arteries and to accomplish hemostasis (median, 65.5 min). Anatomic hemostasis, which was defined as no need for further unexpected hemostatic intervention after the initial procedure, was achieved in 18 patients. The other two patients who failed anatomic hemostasis became two mortality cases with preperitoneal hemorrhage. Although the number of overall mortalities was 9, the remainder did not die from pelvic fracture; rather, from associated traumatic brain injury (Table 4).

The iliac vein was injured during dissection in three cases, which required primary repair in two cases and iliac vein ligation in one case. During the ICU stay (median, 17.5 days), acute kidney injury was identified according to the Kidney Disease: Improving Global Outcomes guideline in 13 patients, likely due to volume depletion. The median ventilator-free days was 13.5. Six patients were confirmed with ventilator-associated pneumonia. Furthermore, 12 patients were diagnosed with acute respiratory distress syndrome per the Berlin criteria. Unfortunately, there was one case where a lower extremity artery was acutely occluded. Emergency femorofemoral bypass surgery was performed; nevertheless, reperfusion injury was inevitable.

Discussion

This retrospective observational study demonstrated the effectiveness and safety of bilateral internal iliac artery ligation with preperitoneal pelvic packing by evaluating pelvic fracture-related mortality and periprocedural complications of 20 critically injured patients. Overall mortality was nine, with only two cases owing to pelvic fracture-related hemorrhage. Uncontrollable exsanguination persisted at more than 200 ml per hour through the drainage

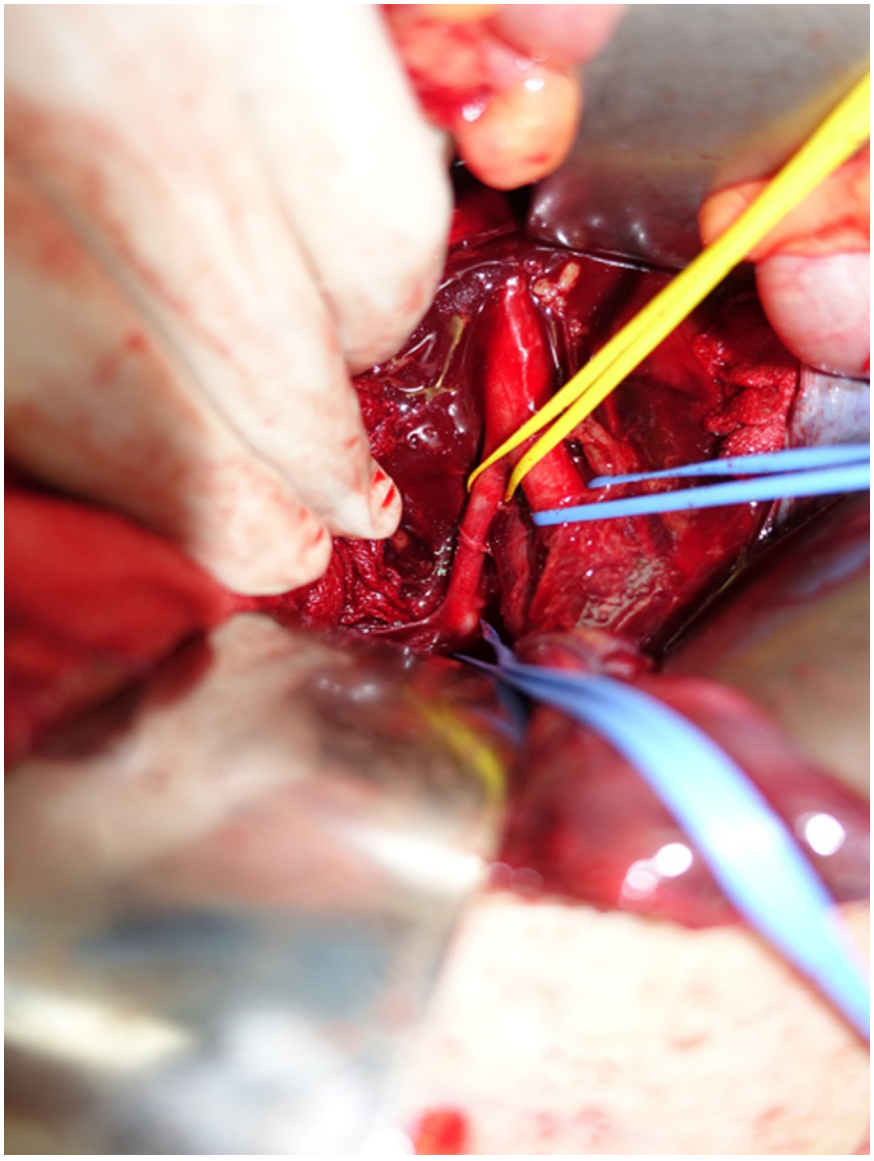

Fig. 2. Identifying the internal and external iliac artery with vessel loops.

catheters in the preperitoneal space of both patients, for which unplanned 2nd look operations were unavoidable within a few hours. However, no definitive arterial or venous bleeding was detected; only oozing exsanguination, likely due to disseminated intravascular coagulation, was identified. Likewise, in one mortality case of intraperitoneal hemorrhage, only non-compressible exsanguination was found throughout the entire abdomen.

The iliac vein is commonly positioned beneath the artery; thus, iatrogenic venous injury can occur inadvertently during dissection. Since the iliac vein lies deep, it is difficult to control when injured, even for experienced vascular surgeons. Serious accidents were incurred in three cases where securing the operation field was challenging due to profuse blood surges. After roughly stitching several sutures, we were just able to manage the patient in this critical phase.

Interestingly, less than 6 h after initial resuscitation with packing and ligation, lower extremity arterial occlusion from a common iliac artery without evidence of traumatic dissection was found in one 85-year-old woman. Considering her pre-medical history of dyslipidemia and medication, and while there were no image studies on admission, we supposed that the lower extremity arterial patency had been narrowly preserved mainly via collateral circulation, including the internal iliac artery, which was disrupted after ligation. To cope with ischemic insult, we performed femorofemoral bypass with extended polytetrafluoroethylene (ePTFE) graft (IMPRA® ePTFE Vascular Graft, Carboflo^{TM} Flex Carbon-Lined, C.R. Bard, Murray Hill New Jersey); however, lethal progress of reperfusion injury was unavoidable, aside from synthetic material being exposed to the temporarily closed wound of preperitoneal space.

A recent review by Patrizio et al. in 2018 summarized that the mortality rate in patients with major pelvic hemorrhage due to fractures who received preperitoneal pelvic packing ranged to 36.3%. Furthermore, when confined to angiographic embolization without the preperitoneal pelvic packing group, the mortality rate skyrocketed to approximately 70% [21]. In the context of mortality, our study suggested that bilateral internal iliac artery ligation could be a lifesaving procedure in major pelvic fractures as an alternative to angiographic embolization. Due to the increased age of the participants in this study, our results showed more favorable outcomes, especially in terms of mortality due to preperitoneal hemorrhage, compared to several studies with a younger cohort. Constantini et al. demonstrated a 32% mortality rate for patients in

Table 4
Outcomes and periprocedural complications.

Variables	Patients with bilateral IIA ligation (n = 20)	
Time to hemostasis, minute	65.5	(41–106)
Anatomic hemostasis	18	(90.0%)
IIV injury	3	(15.0%)
Follow-up, days	75.5	(0–844)
ICU stay, days	17.5	(1–60)
Ventilator free days, days	13.5	(1–60)
Complications		
Stroke	0	(0.0%)
Myocardial infarction	1	(5.0%)
ARDS	12	(60.0%)
VAP	6	(30.0%)
VTE	0	(0.0%)
Colonic ischemia	0	(0.0%)
Buttock claudication	0	(0.0%)
Paresthesia	0	(0.0%)
Wound infection	0	(0.0%)
Skin necrosis	0	(0.0%)
AKI	13	(65.0%)
Aortic occlusive disease	1	(5.0%)
All-cause mortality	9	(45.0%)
CNS	5	(25.0%)
Cardiovascular	1	(5.0%)
Intraperitoneal hemorrhage	1	(5.0%)
Preperitoneal hemorrhage	2	(10.0%)
24-hour mortality	3	(15.0%)
30 days mortality	6	(30.0%)

Data are presented as the number (%) or the median.
IIV, internal iliac vein; ICU, intensive care unit; ARDS, acute respiratory distress syndrome; VAP, ventilator-associated pneumonia; VTE, venous thromboembolism; AKI, acute kidney injury; CNS, central nervous system.

shock. Though there is no detailed description of the salvage procedure for each of the deceased, more than 10% were suggested to be associated with hemorrhage-related mortality [2].

The data for cases that expired due to hemodynamic status and treatment choice was unavailable in this study, but Bonde et al. reported that 10% of the enrolled patients expired due to uncontrolled pelvic bleeding [1]. In a comparative study, Chernobylsky et al. analyzed the survival of internal iliac artery embolization versus Silastic loop ligation for traumatic pelvic hemorrhage control [6]. Unfortunately, overall 57% of the mortality rate was noted with ligation. The relatively old age of the participants in our study could have resulted from the increased working age, a distinctive socioeconomic and cultural feature of Ulsan. As a representative heavy industrial city of Korea still under development, aged workers of the primary industry still co-exist in the heavy industry district within the city boundaries. A lot of aged patients are severely injured under such circumstances.

Moreover, wound infection rates have been reported to be as high as 47% in one large case series, especially in the presence of an associated organ injury [21]. In addition, Travis et al. have reported that patients with internal iliac artery embolization after blunt pelvic trauma had an increase in the occurrence of short and long-term complications, including skin ulceration, thigh or buttock claudication, and other neurologic complications [22]. What is encouraging in this study is that, though followed up shortly, not a single procedure-associated complication such as buttock claudication, colonic ischemia, significant wound infection, or skin necrosis was reported. Concerning buttock claudication, the symptom was not confirmed in this series; nonetheless, such a favorable result might be due to the relatively short follow-up period. Most patients were not ambulatory but in a wheelchair during the study period.

Consequently, they might demonstrate the symptom later with ambulation. Or, the symptom could be misinterpreted as pelvic fracture-related pain. Thus, rather than buttock claudication, the absence of local skin loss would be a useful indicator for the procedure. Gautham et al. have mentioned that the patency of collaterals is important for maintaining pelvic circulation after embolization [23]. Highly selective distal artery embolization can disrupt peripheral circulation by interrupting multiple collaterals [24].

Since the novel concept of the hybrid emergency room arose in 2011, endovascular resuscitation has become popular as a lifesaving procedure for hypovolemic shock thanks to the rapid advances in techniques and equipment. [25,26]. Nevertheless, such innovative workflows are affordable, particularly in certain developed communities. In more austere provinces, interventional radiology suites have hardly been implemented or deployed distant from the trauma bay. Only two out of 17 regional trauma centers in Korea are fully equipped and staffed with interventional facilities and personnel; thus, emergency angiographic embolization in hemodynamically unstable patients is typically unavailable most of the time in most of the trauma centers, including Ulsan University Hospital.

Moreover, the introduction of work-hour restrictions has led to decreased clinical opportunities. Consequently, surgery residents and fellows are getting less experienced. Therefore, considering low volumes (20 cases over 5 years), maintaining critical skill of pre-peritoneal pelvic packing with bilateral internal iliac artery ligation, which is supposed to be performed in unfavorable scenarios, might be warranted for all trainees.

One of the limitations of our study attributes to the insufficiently facilitated circumstances mentioned above. Major concerns in our study included the effectiveness and safety of bilateral internal iliac artery ligation, which would be properly supported if compared with the outcomes of a control group that had other techniques performed. Further studies of comparison between packing with ligation group and packing with embolization group might strengthen our results or suggest inventive conclusions. Also, considering the relatively small volume of patients in a single center, a meta-analysis review with other literature would be helpful to verify the results. In addition, there were no data about temporary ligation of the bilateral internal iliac artery. Comparison between temporary (e.g., Rummel tourniquet) and permanent ligation might present more interesting outcomes, especially concerning complications.

Conclusion

Bilateral internal iliac artery ligation with preperitoneal pelvic packing is considered effective as a lifesaving procedure in hemodynamically unstable patients with a major pelvic fracture in terms of mortality due to fracture-related exsanguination. Moreover, the incidence of periprocedural complications is considered tolerable compared with angiographic embolization. Consequently, we believe the procedure is worth a try in the face of catastrophic uncontrolled hemorrhage, especially in austere, underdeveloped locations.

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