REVIEW ARTICLE

Angiographic embolisation of pelvic ring injuries. Treatment algorithm and review of the literature

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Abstract

Purpose The purpose of this study was to evaluate the relation between pelvic fracture patterns and the angiographic findings, and to assess the effectiveness of the embolisation.
Methods This retrospective study, included patients with pelvic fractures and angiographic evaluation. Demographics, Injury Severity Score (ISS), associated injuries, embolisation time, blood units needed, method of treatment and complications were recorded and analysed. Fractures were classified according to the Burgess system.
Results Between 1998 and 2008, 34 patients with pelvic fractures underwent angiographic investigation. Twenty six were males. The mean age was 41 years. Twenty-seven were motor vehicle accidents and seven were falls. There were 11 anterior posterior (APC) fractures, 12 lateral compression (LC), eight vertical shear (VS) patterns and three with combined mechanical injuries. The median ISS was 33.1 (range 5–66). From the 34 who underwent angiography, 29 had positive vascular extravasations. From them, 21 had embolisation alone, two had vascular repair and embolisation, five required vascular repair alone and one patient died while being prepared for embolisation. Five cases were re-embolised. The findings suggested that AP fractures have a higher tendency to bleeding compared with LC fractures. Both had a higher chance of blood loss compared to VS and complex fracture patterns. We reported 57 additional injuries and 65 fractures. The complications were: one non lethal pulmonary embolism, one renal failure, one liver failure, one systemic infection, two deep infections and two psychological disorientations. Seven patients died in hospital.
Conclusion Control of pelvic fracture bleeding is based on the multidisciplinary approach mainly related to hospital facilities and medical personnel's awareness. The morphology of the fracture did not have a predictive value of the vascular lesion and the respective bleeding.

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Introduction

Pelvic fractures are caused by high energy trauma. Their management requires a multidisciplinary approach due to the increased incidence of associated injuries to other body regions and to the intra pelvic organs [1–3]. Despite the advances made in all disciplines of medicine the mortality rate following pelvic ring injuries remains as high as 13.5% [2].

Hypovolemic shock continues to be one of the major factors contributing to mortality rates following pelvic fractures. Sources of bleeding include the intra-pelvic low pressure venus plexus, disrupted arteries, and the cancellous bone fracture edges or combinations of all of the above. Control of bleeding in the early clinical pathway of these traumatised patients is therefore of paramount importance. Temporary stabilisation of the fractured pelvis with binders [1, 4–6] or external fixation devices (external fixator, C-clamp) combined with pelvic packing and/or angiography have been used with variable results [7–10].

The role of angiography [11, 12] has been a topic of lively discussion lately. Should angiography be used as a primary intervention for control of bleeding? What type of patients would benefit most from this intervention? Should it be considered as a complimentary intervention when other measures have failed?

The purpose of this retrospective study therefore was to evaluate the benefits of pelvic embolisation in our institution. More specifically we felt it important to document the patient demographics, timing of intervention and its efficacy.

Methods

From January 2003 to January 2008 all patients admitted to our institution with blunt trauma were eligible to participate in this study. Inclusion criteria were patients who had sustained pelvic fractures in isolation or combined with polytrauma that required pelvic embolisation as part of their management.

Patients with pathological fractures or patients that underwent angiography for other causes than pelvic bleeding were excluded. For this retrospective study ethics committee approval was obtained. Using our trauma registry, patients that fulfilled the inclusion criteria were identified and formed the study group. Demographic details, mechanism of injury, Injury Severity Score (ISS) [13], associated injuries, haemodynamic status on arrival, resuscitation requirements, timing of pelvic embolisation, overall transfusion requirements, clinical course (post-operative complications), length of intensive care unit stay (ICU), length of hospital stay and mortality were entered in a computerised database for further analysis. Pelvic fractures were classified according to the Young–Burgess Classification [14].

On arrival in the trauma room all patients were managed according to the ATLS protocol. Physiological status of the patient was classified as stable, unstable or extremis [15]. The decision to proceed to angiography was based on the patient's physiological status. According to our unit's protocol (Fig. 1), all pelvic fractures were initially temporarily stabilised with either a pelvic binder or an external fixator. The minimum follow up was 12 months (12–48).

Statistical analysis

Statistical analysis of the data was performed using the Statistical Package for the Social Sciences (SPSS), version 16.0 (SPSS, Inc., Chicago, IL, USA). All quantitative variables were expressed as means ± standard deviation (SD), and they were analysed using the Mann-Whitney U-
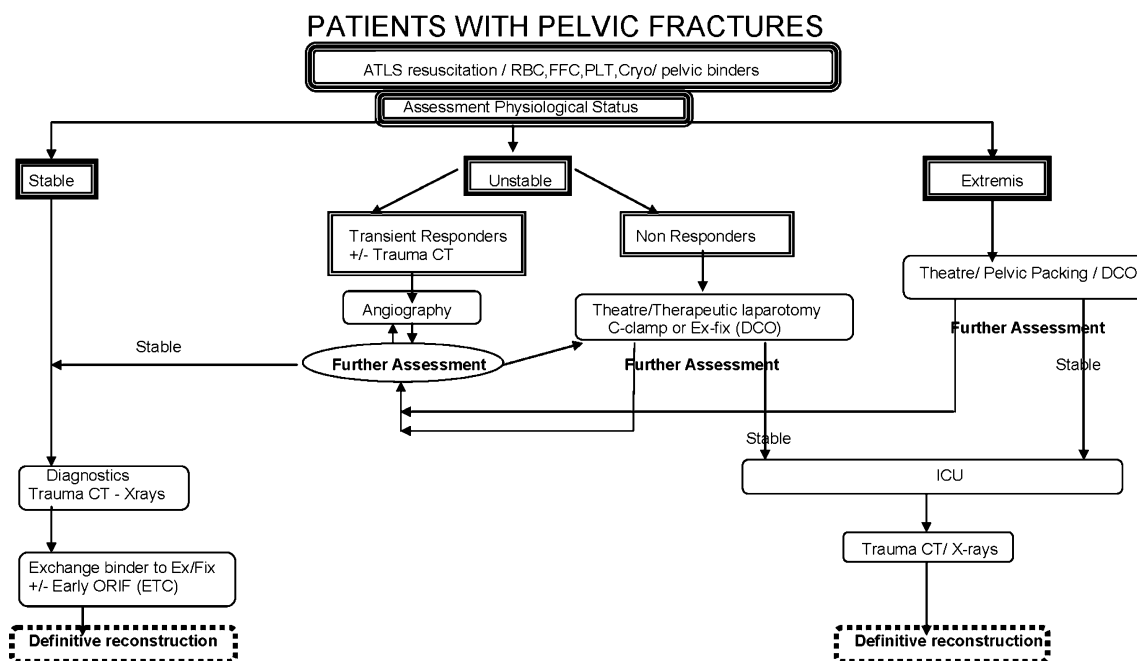

Fig. 1 Pelvic fracture management and suggested treatment algorithm

test and the Kruskal-Wallis test to assess differences between two or more groups of patients, respectively. Post hoc analysis was performed using Mann-Whitney U-test with adjusted level of significance at $\alpha=0.01$. The normality of quantitative variables was tested with the Kolmogorov–Smirnov test.

Results

Out of 400 patients that were admitted with pelvic fractures during the pre-specified study period, 34 (8.5%) met the inclusion criteria. There were 26 males and eight females with a mean age of 41 years (range 14–97). Mechanism of injury included 27 motor vehicle accidents (79%) (eight drivers and three passengers, seven pedestrians, eight motorcyclists, and one cyclist). A fall from height (over 2 metres) was the cause of injury in seven patients (21%). According to Young–Burgess classification [14], there were 11 anterior posterior (APC) fractures, 12 lateral compression (LC), eight vertical shear (VS) and three with combined mechanism injuries (Table 1). There were four open pelvic fractures.

The overall mean ISS was 33.1 (range 15–66). Five patients with negative angiography had a mean ISS of 22 (17–29); whereas in 29 patients with positive findings the mean ISS was 35.5 (15–66), ($p=0.005$). All 34 patients had at least one or more concomitant fracture or injuries, with a total of 57 additional injuries (11 CNS injuries, one oesophageal contusion, 16 chest injuries [16 with haemothorax and ten patients with lung contusion], 15 abdominal injuries [four bowels, three spleen, seven liver, one mesentery], seven urinary track injuries [one testis haematoma, one prostate rupture, two bladder rupture, three urethra rupture], two involving major vessel injuries and two eye injuries).

Furthermore, there were 65 additional fractures involving: spine with seven vertebral fractures, chest with 13 ribs

and three sternum fractures, upper limb with 20 fractures and lower limb with 22 fractures. From those 65 fractures, 30 (46%) of them required further operative management.

Haemodynamic status was very variable on admission in terms of fluctuation for both the systolic and diastolic pressures. The lowest systolic and diastolic pressures documented were 56 mmHg and 30 mmHg, respectively. The mean heart rate was 98 bpm (range 144–47).

The pelvic fracture was initially temporarily stabilised with an external fixator in 21 patients. Thirteen patients were managed with pelvic binders, all subsequently converted to external fixation until definitive stabilisation of the pelvic fracture. Ten patients underwent laparotomy, three splenectomy, six urinary track repair and four craniotomies. Definitive reconstruction of the pelvic ring was performed at a mean time of six days (range four to 16). In 21 patients external fixation was revised to ORIF. In six patients external fixation was maintained as the definitive stabilisation method without any other intervention, whereas in seven patients external fixation was complimented by the insertion of sacroiliac screws for stabilisation of the posterior pelvic elements. The method of fixation of the pelvic fracture was dictated by the state of the soft tissues, the type of fracture, the degree of initial reduction and stability achieved and from the age of the patient.

Angiography-embolisation

Out of 34 patients, 29 had positive findings of extravasations, of which 21 had embolisation alone (19 within four hours from arrival to the trauma room and two within 24 hours) and two had embolisation and vascular repair with vascular stent. Five were considered unstable-non responders and had open vascular repair (three died), and one patient died while being prepared to undergo embolisation.

Table 1 Fracture patterns analyzed in relation to angiographic findings, embolisation, vascular operations and mortality

Fracture category	Subcategory	Number	Extravasations	Embolisation	Vascular operation	Deaths
Lateral compression (LC)	I. Sacral compression on the side of injury	3	2	2		
	II. Iliac wing fracture	1	1	1		1
	III. Controlateral open book injury	8	7	5	2	2
Anterior-posterior compression (APC)	I. Stretched but intact anterior and posterior ligaments (open book)	1				
	II. Disrupted anterior/ intact posterior	2	2	2		
	III. Complete anterior and posterior disruption	8	8	7	3	
Vertical shear (VS)	Vertical displacement through SI-Joint, wing or sacrum	8	8	6	2	3
Combined mechanism		3	2	2		1 later
Total		34	29	25	7	8

Table 2 The location of the embolisation and the respective numbers

Location of embolisation (25 patients)	Number of vessels embolised
Internal iliac artery	12
Gluteal artery	9
Hepatic	2
Internal pudendal artery	5
Colic artery	1
Obturator artery	1
Splenic	2
Renal	1
Sup circumferential artery	1
Iliolumbar artery	1
Total	35

The patients with positive extravasations during the first 72 hours received 333 units of blood; mean number of blood units was 11.48±7.55. The five patients with negative angiography had received 14 units of blood in the first 72 hours with a mean number of 2.80±1.95 units ($p=0.021$). In five cases (24%) angiography was repeated, four the next day and one eight days later due to the development of a pseudoaneurysm. Overall, embolisation was successful in all but one case, as in this specific patient the same artery had to be re-embolised. For the other four re-embolisations a secondary source of bleeding was identified.

In total 35 vessels underwent angiographic embolisation. The location mainly involved the internal iliac artery (12 vessels embolised) and the gluteal artery (nine vessels embolised) (Table 2). The most common coils used were stainless steel coils, gel foam and spongustant flurry.

All the patients with vertical shear (VS) fracture pattern had a positive angiogram, whereas ten of 11 of the anterior posterior (APC) fractures, nine of 12 of the lateral compression (LC) and two of three of the combined mechanism fracture pattern had positive extravasations. The relationship between fracture pattern and bleeding in the first 24 hours of admission and the following 48 hours (post embolisation) is shown in Table 3.

The APC fracture patterns were found to have a slightly higher tendency to bleeding compared to lateral compression fractures but the difference did not reach statistical significance ($p=0.913$). Data analysis demonstrated that during the subsequent 48 hours APC, VS and combined mechanism fracture patterns had a tendency for higher requirements in blood transfusion compared to the LC fractures ($p=0.680$) (Table 4).

No statistically significant differences were found between the four fracture categories in relation to the necessity of RBC, PLT and Cryo in the first 24 hours or subsequent 48 hours following admission to hospital. The only exception was the use of FFP ($p=0.016$), which was significantly lower in combined mechanism fractures compared to the other three categories.

The mean ICU stay for the survivors was 11.9 days (range 0–34) and the mean hospital stay was 38.9 days (9–130).

Mortality

Seven patients (five males, two females) (20.6%) died during admission to hospital, five within 24 hours, of which two were from hypotension/bleeding, one hypotension/ bleeding due to abdominal injuries and two cases from multiple trauma (mainly head injuries). One patient died at 48 hours following his CNS injuries, whereas the other died on day seven due to multisystem organ failure syndrome. Another male patient who was in hospital for 40 days, died within a month post discharge of unknown cause. Therefore, the overall mortality rate in this series was 8/34 (23.5%). The relation between fracture pattern, angiographic results, embolisation, vascular surgery and mortality is presented in Table 1. From the angiographic point of view, out of these eight patients, two had negative findings. Three underwent embolisation, two had embolisation together with vascular repair and one had vascular repair alone.

The survivors were younger with a mean age of 38 years (range 16–87) compared to non-survivors, mean age of 52 years (range 26–97) ($p=0.031$). The mean ISS was 30.85 (range 5–66) in survivors compared to 38.75 (range 16–66) in non survivors ($p=0.041$).

Table 5 illustrates the comparison between the fatalities and survivors and the respective post injury requirements in blood units and substitutes. Patients who died had a higher requirement for blood ($p=0.011$) and FFP ($p=0.063$) both pre and post embolisation.

Complications

During the peri-operative period, one patient had a non lethal pulmonary embolism, one a fat embolism, two renal and one liver failure and one chest infection. Additionally, two patients developed deep infection over the symphysis pubis stabilisation, which necessitated irrigation of the wound and a course of intravenous antibiotics.

Discussion

The management of patients with pelvic fractures is challenging and requires several disciplines. The clinical condition of the patient can deteriorate rapidly, hence clinicians must be aware of all the important issues governing the initial management of these patients. The

Table 3 Evaluation of fracture pattern, blood units and substitutes required in the first 24 and the subsequent 48 hours

Fracture category	Occurrence[a]	RBC	FFP	PLT	Cryo
Lateral compression (LC); 12/12 patients	First 24	148 mean 12.3 (range 0–52)	59 mean 4.9 (range 0–28)	16 mean 1.3 (range 0–7)	11 mean 0.9 (range 0–6)
	Next 48	15 mean 1.25 (range 0–4)	14 mean 1.2 (range 0–2)	6 mean 0.5 (range 0–1)	1 mean 0.08 (range 0–1)
Anterior-posterior compression (APC); 9/11 patients	First 24	111 mean 13.9 (range 0–39)	46 mean 5.8 (range 0–22)	11 mean 1.4 (range 0–6)	12 mean 1.5 (range 0–10)
	Next 48	23 mean 2.6 (range 0–8)	20 mean 2.5 (range 0–4)	8 mean 1 (range 0–2)	-
Vertical shear (VS); 7/8 patients	First 24	67 mean 9.6 (range 0–33)	15 mean 2.1 (range 0–8)	-	1 mean 0.1 (range 0–1)
	Next 48	19 mean 2.7 (range 0–10)	13 mean 1.9 (range 0–3)	12 mean 1.7 (range 0–8)	8 mean 1.1 (range 0–8)
Combined mechanism; 3/3 patients	First 24	21 mean 7 (range 3–10)	10 mean 3 (range 0–6)	1 mean 0.3 (range 0–1)	2 mean 0.7 (range 0–2)
	Next 48	8 mean 2.7 (range 0–5)	-	-	-
Total	First 24	347 mean=11.1	130 mean=4.1	28 mean=0.9	26 mean=0.8
	Next 48	65 mean=2	47 mean=1.5	26 mean=0.8	9 mean=0.3
	Combined total	412	177	54	35

[a] During the first 24 hours of admission and the following 48 hours (post embolisation)

RBC red blood cells, *FFP* fresh frozen plasma, *PLT* platelets, *Cryo* cryoprecipitate

observation that decisions involved the simultaneous input from different subspecialties led to the development of an algorithm so that life-saving actions could be implemented immediately without any arguments or delays. Based on the setup of each trauma unit a protocol is usually developed to accommodate the local resources and manpower [1, 16–18]. Whilst there might be minor differences between algorithms, the overall objective remains to achieve the end points of resuscitation, correction of hypovolemia and coagulation disturbances, which could be detrimental in the survival of the traumatised patient. The algorithm developed in our centre (Fig. 1) allows efficient use of our resources and timely intervention for the restoration of haemodynamic stability.

Quite a few algorithms have been previously introduced with many similarities with respect to the initial treatment approach of pelvic ring fractures [1, 5, 17–21]. Stein et al.

[1] based their treatment protocol on the initial findings of the FAST (Focused Assessment with Sonography in Trauma) or the Trauma CT. Other authors [21] have based their algorithm on the FAST following a similar treatment protocol with ours. Cook et al. [20] based their treatment protocol on the increased incidence of APC and VS fractures. Others divided the patients into two groups based on the clinical status (stable or unstable) [5, 19].

Dyer et al. [17] used the OTA /AAST algorithm and based their treatment on the initial patient assessment, X-ray findings and whether the pelvic fracture was an open or closed injury. Van Vugt et al. [18] focused their patient management on the initial FAST, X-ray findings and the presence of hypovolaemic shock. We preferred to perform early trauma CT as it is more informative than either plain X-rays or FAST examination. Recently, immediate CT for major trauma and rapid diagnosis has allowed the initiation

Table 4 Statistical analysis of blood units, substitutes requested and the fracture pattern

Clinical data	Fracture category				
	LC (n = 12)	APC (n=9)	VS (n=7)	CM (n=3)	p
First 24 hours of admission					
RBC					0.913
Total	148	111	67	21	
Mean ± SD	12.42±14.44	12.33±12.83	9.57 ±12.67	7.00±3.61	
Range	0–52	0–39	0–33	3–10	
FFP					0.719
Total	59	46	15	10	
Mean ± SD	4.92 ±7.65	5.11±6.75	2.14±2.79	3.33±3.06	
Range	0–28	0–22	0–8	0–6	
PLT					0.080
Total	16	11	0	1	
Mean ± SD	1.42±2.11	1.33±1.94		0.3±0.58	
Range	0–7	0–6		0–1	
Cryo					0.650
Total	11	12	1	2	
Mean ± SD	0.92±1.73	1.33±3.28	0.14±0.38	0.67±1.15	
Range	0–6	0–10	0–1	0–2	
Next 48 hours (post embolisation)					
RBC					0.680
Total	15	23	19	8	
Mean ± SD	1.25±1.29	2.56±2.83	2.71±3.45	2.67±2.52	
Range	0–4	0–8	0–10	0–5	
FFP					0.016
Total	14	20	13	0	
Mean ± SD	1.17±0.71	2.44±1.50	1.86±1.07		
Range	0–2	0–4	0–3		
PLT					0.118
Total	6	8	12	0	
Mean ± SD	0.50±0.52	1.00±0.70	1.71±2.87		
Range	0–1	0–2	0–8		
Cryo					0.655
Total	1	0	8	0	
Mean ± SD	0.08±0.29		1.14±3.02		
Range	0–1		0–8		

APC anterior posterior fractures, *LC* lateral compression, *VS* vertical shear, *SD* standard deviation, *RBC* red blood cells, *FFP* fresh frozen plasma, *PLT* platelets, *Cryo* cryoprecipitate

of targeted treatment interventions. Such practice has revolutionalised the management of polytrauma patients.

Several authors have attempted to define specific parameters that would be indicative and would assist the clinician to request angiography. Totterman et al. [8] reported that in haemodynamically unstable patients who had a minimum of three of the following clinical signs: tachycardia, delayed capillary refill >2 sec, hypotension <90 mmHg, reduced level of consciousness, or reduced pulse pressure, angiography should be requested. Indications for angiography as described by other authors include the requirement for more than four units of blood during the first 24 hours [18, 22, 23], the presence of a high ISS [2], a high pelvic AIS, blood transfusion rate greater than 0.5 unit/hour, decreased base excess level [24], and finally a haemodynamically unstable pelvic fracture [25]. Salim et al. [26] presented an algorithm attempting to estimate the probability of therapeutic angiography. Logarithm odds of therapeutic angiography=−1.408+(1.361×gender female)+(1.497× presence of SIJ disruption)+(0.364 × minutes of SBP <100 mmHg during first 2 hours / 15). If all three factors are present there is a 90% of necessity for angiographic embolisation, which decreases to 20% if all factors are absent.

Prognostic parameters indicative of a positive outcome following angiographic embolisation include persistent hypotension, female gender, age over 55, disruption of the posterior pelvic elements, ISS >25, and GCS <8 [16, 26–

Table 5 Statistical analysis between survivors and fatalities, comparing the age, ISS score, admission blood pressure, heart rate and blood units and substitutes required

Parameter	Non survivors mean (N=8)		Survivors mean (N =26)		P value
Age (years)	52.50±12.15 (range 26–97)		38.3±15.80 (range 4–87)		0.031
ISS	38.75±8.70 (range 16–66)		30.85±8.65 (range 5–66)		0.041
Blood pressure					
Systolic (S)	120 ±14 (range 142–98)		117±13 (range160–56)		0.579
Diastolic (D)	78±10 (range 125–49)		72±9 (range110–30)		0.118
Heart rate	94±6 (range 133–70)		99±7 (range133–47)		0.016

Parameter	n	Mean ± SD	n	Mean ± SD	P value
First 24 hours of admission					
RBC	87	12.40±7.84	260	10.80±9.40	0.881
FFP	33	4.71±5.55	97	4.12±6.87	0.930
PLT	7	1.05±1.48	21	0.88±1.12	0.645
Cryo	0	0	26	1.08±2.05	0.229
Next 48 hours (post embolisation)					
RBC	32	4.60±6.20	33	1.37±0.80	0.011
FFP	15	2.14±1.85	32	1.33±0.71	0.063
PLT	5	0.72±1.35	21	0.88±1.05	0.849
Cryo	7	0.98±0.77	2	0.08±0.30	0.024

RBC red blood cells, *FFP* fresh frozen plasma, *PLT* platelets, *Cryo* cryoprecipitate

28]. According to Agolini et al. [3] patients who were embolised within three hours of arrival had a significantly greater survival rate. On the other hand Wong et al. [29] reported that death risk increased by 62% for every 1 unit/hour increase of transfusion rate. Moreover, Geeraerts et al. found that transfusion of more than 2 units/hour prior to initial embolisation and more than two arteries embolised were predicting risk factors for repeated embolisation [16]. Similarly, Shapiro et al. [30] reported three independent risk factors for recurrence of bleeding and need for re-embolisation: (a) systolic arterial pressure below 90 mmHg after embolisation, (b) acidosis (base deficit >10 mEq/l) persisting for more than six hours after initial embolisation and (c) absence of intra-abdominal haemorrhage.

The majority of the patients that underwent angiography in this study were hypotensive and transient responders. Following initial resuscitation, all underwent angiographic embolisation based on their response to treatment. A literature review that was performed including studies published during the last 30 years indicates that there were different protocols and criteria applied for the selection of patients undergoing angiography (Table 6). In a total of 9,627 cases of pelvic fractures, the mean age of the patients and the mean ISS were 39 years and 30.9, respectively. Of them, 805 (8.4%) underwent angiography and 573 (71%) had embolisation of the bleeding vessel. The non-survivor rate was approximately 26% but it is evident that there were remarkable variations between mortality rates from one study to another ranging

from 5.5% [31] to 61% [27]. The overall mortality rate in our series was 8/34 (23.5%), comparable with the mean percentage of mortality rate (26%) in the review of 25 studies (Table 6). We were unable to determine whether failure to achieve embolisation correlated to an increased mortality rate as these data are not available in the existing literature. The overall blood transfusion requirements was difficult to evaluate for patients who underwent angiography compared to those who didn't, as this information was not available in the majority of the papers analysed. It was not possible to calculate the mean time from injury to angiography as this information was not provided in the majority of the reports.

Complications related to angiographic embolisation should be considered although they are not frequently presented. A recent study from Travis et al. [32] addressed the differences between short- and long-term complications. No significant differences in skin necrosis, sloughing, pelvic perineal infection, or nerve injury between embolised and non-embolised patients within 30 days from injury were found. Similarly, no differences were reported with claudication, skin ulceration, or regional pain incidence within a mean time of 18.4 months follow-up. On the other hand, for the same period (18.4 months), buttock, thigh, and perineal paresthesia occurred at a significantly higher rate in embolised patients. Other complications that have been reported include cases with necrosis of the visceral wall [33] or the femoral head [34], sensitivity problems [35] or dissemination of the embolism [36]. In this study, no

Table 6 A review of 25 studies

Authors	Number of patients	Mean age, years (range)	ISS	Pelvic angiography	Embolisation	Mortality
Mattalon et al. [37]	324	42(12–83)	n/a	28/324	18/28	9/28
Gilliand et al. [31]	100	29 (15–82)	38.2	19/100	17/19	1/18
Mucha et al. [19]	533	48.6/55.3/35.8	54.1	13/533	11/13	5/13
Panetta et al. [22]	600	44.4 (16–86)	n/a	29/600	27/29	11/29
Moreno et al. [45]	538	36 (20–95)	25.5	7/538	3/7	1/7
Evers et al. [51]	245	36 (14–87)	Divided into 6 groups	16/245	9/16	8/16
Burgess et al. [14]	162	32	26	22/210	22/210	
Agolini et al. [3]	806	35.7 survivors / 64.8 not survivors	38	35/806	15/35	15/35
Perez et al. [46]	721	45 (18–76)	36 (8–57)	8/721	5/8	2/8
Wong et al. [29]	507; 22 analysed	24.6 (16–47)	41.1	17/507	17/17	3/17
Pereira et al. [47]	290	42	32	9	9/9	none
Sriussadaporn et al. [52]	170	34 (15–91)	18(4–75)	16/170	10/16	6/16
Velmahos et al. [39]	100	40 angio/ 33 others	42 positive, 26 negative	100	80/100	14/100
Cook et al. [20]	150	40 (8–88)	20 (9–75)	23/150	18/23	6/23
Hagivara et al. [53]	269	39.5	38.2	41/234	19/41	2/41
Shapiro et al. [30]	678	39 all/ 44 angiography		31/678	16/31	4/31
Kataoka et al. [38]	72	42.9	34.4	72	61/72	18/61
Sarin et al. [40]	283	45 embolised, 39.9 others	35.6 embol, 29.2 no	37/283	37/37	13/37
Fangio et al. [23]	311	39	39	32/311	25/32	10/32
Sardi et al. [54]	55	40.5	25.2	14/55	5/14	2/14
Totterman et al. [8]	1260	40 (9–82)	41(17–66)	46/1260	31/46	5/31
Basel et al. [55]	42/604	46.8 angiography, 40.3 remain	24.5 positive, 18.3 negative	25/604	17/25	10/25
Sanchez Tocino et al. [27]	192	40 (15–91)	28.5	16/192	4/16	10/16
Salim et al. [26]	603	38.4	17.3	137/603	85/137	
Fu et al. [25]	54	41.1	14.3	12/54	12	
Total patients	**9,627**	**Mean age 38.8**	**Mean ISS=30.9**	**805/9627=8.4%**	**573/805=71%**	**155/598=26%**
Present study	400	41 (4–97)	33.1 (15–66)	34 (8.5%)	23/43 (53.5%)	8/34 (23.5%)

ISS Injury Severity Score, *n/a* not applied

patient sustained skin necrosis, perineal infection or perineal paresthesia following embolisation.

The effectiveness of the angiographic embolisation in the literature [3, 8, 20, 23, 29, 30, 37–40] varies from 59% presented in Kataoka et al. series [38] to as high as 100% in other series [3, 29, 30]. The effectiveness rate reached 95.7%, which is similar to the study of Velmahos et al [39]. Angiographic embolisation (AE) is considered as effective when no radiological signs of extravasations are seen on angiography after embolisation, when no further interventions in the form of repeat embolisation or pelvic packing are required and when patients survive the first 24 hours after the procedure [8].

Numerous authors have investigated whether any correlation exists between different fracture patterns and pelvic bleeding [14, 40–44]. The results are questionable as most of the studies focused on the more severe fracture patterns (VS, APCIII injuries) [3, 19, 20, 26, 37, 45–47]. However, at the same time other studies reported major pelvic bleeding secondary to less severe types of pelvic ring fractures [41–44, 48, 49]. It has been suggested that the morphology of the fracture does not have a predictive value for the vascular lesion identified on angiography. Others believe that the energy absorbed during the accident together with the impact exerted on the pelvic fracture facilitating displacement are more likely to be related to the type of arterial lesion sustained [8, 20].

Limitations associated with the use of angiography must also be considered. Firstly, angiography is a time consuming procedure and involves transportation of the patient to

the angiography suite. For this reason, the location of the suite must be very close to the trauma room so that no time is wasted moving patients unnecessarily long distances, risking destabilising the physiological status and thus initiating a vicious cycle of ongoing bleeding. Secondly, it demands 24 hour availability of a well trained interventional radiologist. Thirdly, the main target of embolisation is to selectively isolate the source of arterial bleeding, avoiding causing ischemia and possible necrosis to larger than necessary areas, often not evident due to collateral circulation from the hypogastric artery. In the presence of hypotension (systolic blood pressure <90mmHg), there is also a possibility of a false negative angiography and nearly 50% of the patients who undergo embolisation may have a secondary vascular injury that is not initially identified [50]. Finally, only a small number of cases are usually associated with arterial bleeding. Reviewing the literature it has been calculated that 8.4% of pelvic fractures with haemodynamic instability are secondary to disruption of the arterial tree and would benefit from angiography and only 71% of them will undergo embolisation (Table 6).

Conclusion

A multidisciplinary approach is essential for the management of pelvic fracture bleeding. In the literature a pathway for the timing of angiography or other intervention is not well established for haemodynamically unstable patients. The optimum management depends on the availability of hospital facilities and experienced medical personnel.

The increased mortality rate seen following high energy pelvic fractures is related to bleeding but also to the presence of concomitant injuries. Awareness and early detection of high risk patients is crucial for appropriate selection and effective management with angiography. Our study supports the view that temporary pelvic stabilisation with angiographic embolisation can be a reliable and valuable treatment modality in pelvic fractures associated with arterial bleeding. Due to the severity of the trauma sustained however the mortality rate in this cohort of patients remains high.

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