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The orthopedic damage control in pelvic ring fractures: when and why-a multicenter experience of 10 years´ treatment

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ABSTRACT

Objectives: To report our experience of regional referral center for the pelvis. **Methods:** We treated 526 pelvic fractures from January 2004 to December 2014 in three regional reference centers for pelvic trauma. Men were 480 and women were 46 and ages ranged from 16 to 93 years old. Car (65%) and farm (20%) crashes were the most frequent causes of pelvis fractures. Injury severity scores ranged from 9.0 to 75.0, with a mean of 37.5. A defined algorithm for fracture management has been in place and employed to assure adequate resuscitation and fracture care. **Results:** There were 24 deaths in total (4.56%). Sixty three (11.98%) patients underwent angio-embolization for control of bleeding (12 deaths). The average amount of blood transfused was 8.3 IU. Hospital lengths of stay ranged between 1-35 days. Among the 502 alive patients, 55.98% were able to be discharged at home while the remaining 44.02% being transferred to various rehabilitation facilities or extended care facilities. **Conclusions:** The goal of initial management is to restore vital indicators, urinary excretion function and protect the patient from infectious complications. An emergency decisional algorithm helps manage hemodynamic instability. Initial bone and ligament procedures should reduce displacement and make it possible for the patient to wait until his condition is stable enough for definitive surgical fixation.

1. Introduction

The severe fractures of the pelvic girdle in patients with multiple trauma often require a stabilization in emergency. The pelvic ring fractures are not uncommon and occurr within the severe trauma, and it is a complex problem that often requires for proper conservative or surgical treatments. specialized professional skills such as those of the surgeon of casualty, the radiologist, traumatologist-orthopedist, urologist and eventually the neurosurgeon are required[1]. The pelvic fractures are by high-energy pelvic fractures (HE-PRFs) and low-energy pelvic fractures (LE-PRFs). The incidences of HE-PRF and LE-PRF were 23 per 100 000 persons in New South Wales region in Australia[2], and the mortality was 23% divided into: HE-PRF: 7%; LE-PRF: 2%; prehospital deaths (PD-PRF: 33%)[2]. In a German multicentric study, among 3 260 patients with pelvic and acetabular fractures, 61.7% of the patients were multiply injured; 12.2% were suffering a complex pelvic trauma defined as a pelvic injury with concomitant soft tissue injury[3].

The pelvis is a bony structure complex, consisting of several segments that form a solid ring, which protects organs (vascular structures, genital, urinary and gastrointestinal) it contains[1]. The pelvic ring fractures account for 3%-4% of all fractures and occur with an incidence of 20% in poly-traumatized patients, which can be considered a reliable indicator of high-energy trauma[1].

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The structural damage can be due to a car accident (60%-80%), the fall from the top (10%-30%) or a trauma crush (5%-10%)[1]. Direct result of the intensity of the trauma is the high frequency (90%) of lesions associated to other parts of the body, especially to the central nervous system and the trunk, which often adversely affect the patient's prognosis[1]. This type of fracture is a significant disease because it is burdened with high social costs. In fact, it is common in the age groups of younger (first cause of death in the first four decades of life) with a high mortality rate and with a high percentage of post-traumatic comorbility often disabling, such as chronic pain, abnormal gait, neurological deficits and urinary and sexual problems (incontinence, impotence in men and alterations in the birth canal in women), so about 70%-80% of patients do not resume work activities prior to the pathological event[1]. We report our experience of regional reference centers for pelvic trauma.

2. Materials and methods

Our perspective research was conducted from January 2010 to December 2014 at the U.O.C. Orthopedics and Traumatology, Gaetano Rummo in Benevento, Italy; U.O.C. Orthopedics and Traumatology Universitaria, AOUS Policlinico Santa Maria alle Scotte in Siena, Italy and Orthopedics and Traumatology, Klinical Center University of Banja Luka Bosnia and Herzegovina. We treated 526 consecutive patients with pelvic ring fractures.

This group of patients was composed of 526 patients with an average age of 34.6 (range 16-93) and gender ratio (M: F) of 6.08:1 (280:46) (Table 1). The range of age are: 16-35 years old (n=242; 46.00%), 36-50 years old (n=226; 42.97%), 51-59 years old (n=40; 7.60%) and >60 yaers old (n=18; 3.43%).

Before trauma, patients' occupations consisted of agricultural activity, industrial sector, tertiary industry and unoccupied (Table 1). Types of trauma accidents experienced by patients were fall from height, traffic accident, agriculture accident and other accidents (Table 1).

The pelvic ring fractures were classified with Tile's classification[1] in patients as stable in 24.8% (type A injury), rotationally unstable in 44.7% (type B injury), and unstable in translation in 30.5% (type C injury) of the patients (Table 1).

All patients entering the emergency room had the XR standard and computed tomography (CT) with 3D reconstructions and pre-operative examinations. At admission to the emergency room, the 526 patients had an average injured severity score of 37.5 point (range 9-75) and they had the following associated injures: cerebral concussion, fat embolism, hemopneumothorax, liver injuries, spleen injuries, bowel injuries, urogentital injuries, femur injuries, tibia injuries, rib fractures, clavicle fracture, humerus fractures, forearm fractures, metatarsal fractures, patella fractures, acetabulum fracture, spine fractures, ankle fractures and wrist fractures (Table 2).

Table 1
Descriptions of population.

Description of population		Values
Numbers of patients		526
Average age of patients		34.6
Range of age of patient		16-93
Gender ratio (M: F)		6.08:1 (280:46)
Range of ages [n (%)]	16-35 years old	242 (46.00%)
	36-50 years old	226 (42.97%)
	51-59 years old	40 (7.60%)
	>60 years old	18 (3.43%)
Work of population [n (%)]	Agricultural activity	148 (28.13%)
	Industrial sector	258 (49.05%)
	Tertiary industry	102 (19.39%)
	Unoccupied	18 (3.43%)
Type of accident [n (%)]	Fall from height	56 (10.65%)
	Traffic accident	342 (65.00%)
	Accident agriculture	105 (20.00%)
	Other accidents	23 (4.37%)
Type of fractures according to Tile's classification [n (%)]	A	130 (24.80%)
	B	235 (44.70%)
	C	161 (30.50%)

Table 2
Description of injured severity score and associated injures in the floating knee.

Description		Values
Average range injured severity score		37.5
Range injured severity score		9-75
Injuries associated with pelvic ring fractures [n (%)]	Cerebral concussion	88 (16.73%)
	Fat embolism	12 (2.28%)
	Hemopneumothorax	96 (18.25%)
	Liver injuries	34 (6.46%)
	Spleen injuries	16 (3.04%)
	Bowel injuries	10 (1.90%)
	Urogentital injuries	27 (5.13%)
	Femur Injuries	57 (10.83%)
	Tibia injuries	61 (11.60%)
	Rib fractures	124 (23.57%)
	Clavicle fractures	12 (2.28%)
	Humerus fractures	24 (4.56%)
	Forearm fractures	32 (6.08%)
	Metatarsal fractures	29 (5.51%)
	Patella fractures	33 (6.27%)
	Acetabulum fractures	79 (15.02%)
	Spine fractures	74 (14.06%)
	Ankle fractures	12 (2.28%)
	Wrist fractures	16 (3.04%)
Type of treatment in first surgery [n (%)]	External fixation	352 (84.12%)
	C-clamp	10 (8.92%)
	Pubis belt	22 (6.96%)
	Circumferential sheeting	22 (4.18%)
	Conservative	120 (22.81%)
Average glasgow coma score		12.5
Rage glasgow coma score		8-15
Hemodynamic stability [n (%)]	Stable	439 (83.47%)
	Unstable	87 (16.53%)
Type of treatment in hemodynamic instability [n (%)]	Packing	24 (4.56%)
	Angio-embolization	63 (11.98%)

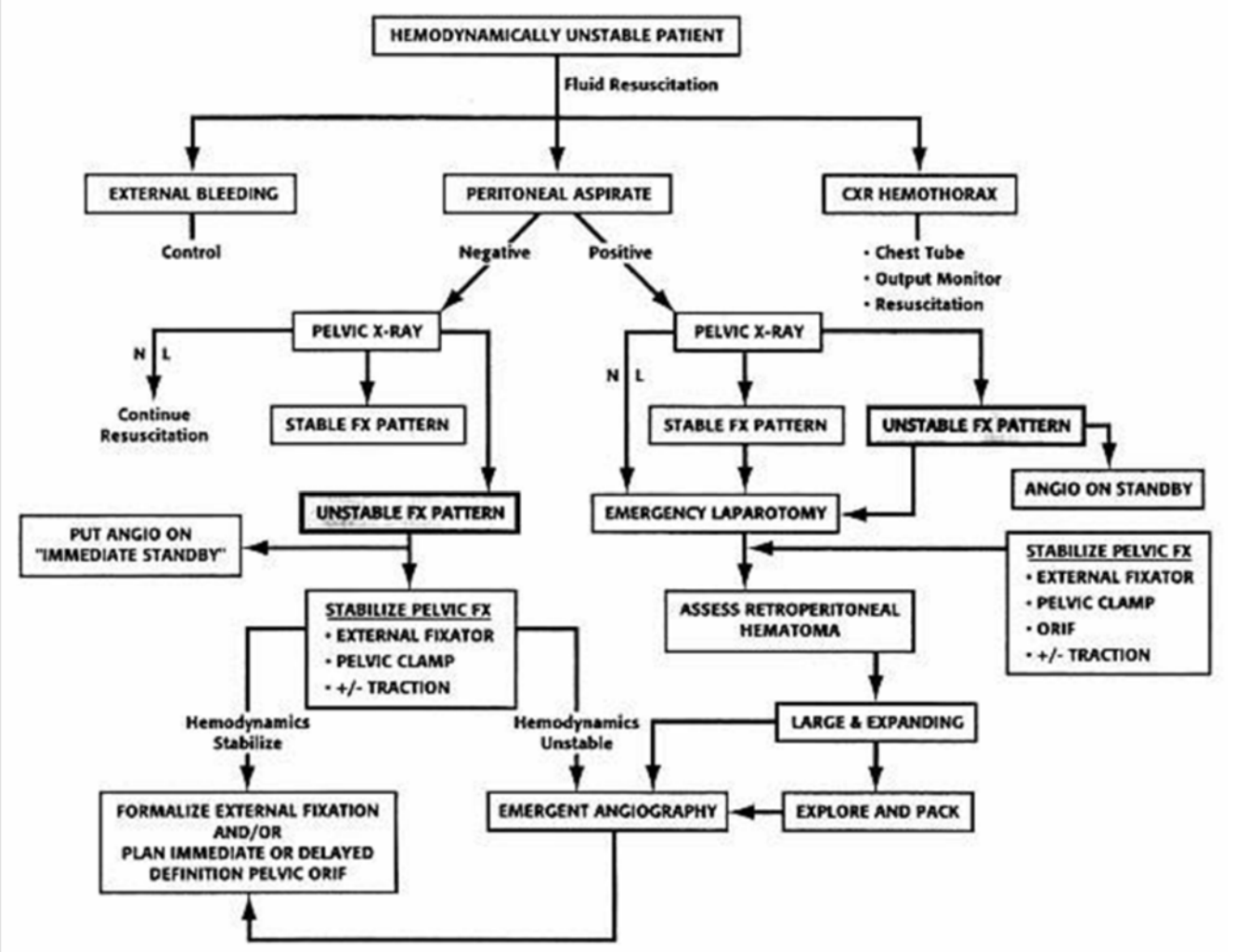

Figure 1. Alghorithm of treatment of hemodynamically unstable patient suffered of pelvic ring injuries[4].

Upon admission to the emergency room the patients had an average glasgow coma score of 12.5 points (range 8–15) (Table 2). We performed the initial emergency orthopedic treatments according an algorithm[4] and pyramid of total care (Figures 1 and 2). A total of 439 patients (83.47%) were hemodynamic stable, while 87 (16.53%) unstable. The 87 pathients were treated by packing in 24 cases (4.56%) and angio-embolization in 63 patients (11.98%) (Table 2).

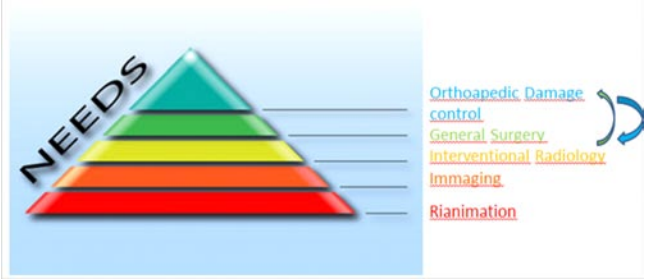

Figure 2. The pyramid of total care in pelvic ring injuries.

The orthopedics damage control was performed by external fixation in 352 (84.12%) patients; C-clamp in 10 patients (8.92%); pubis belt in 22 patients (6.96%); circumferential sheeting in 22 patients (4.18%) and conservative in 120 patients (22.81%) (Table 2). Patients were treated according to the Helsinki Declaration of ethical standards.

The criteria chosen for the evaluation of the treatments was: mortality, amount of blood transfused, length of permanence in hospital, type of demission, miscellanea complication during the treatment in hospital.

Patients were excluded if they died before arriving at hospital. The data were imported in an electronic spreadsheet for further processing and statistical analysis.

3. Results

Tweenty four patients died in this group (4.56%) during the permanence in hospital, among which 12 (2.28%) patients died during the angio-embolization for cardiac and pressure shocks. The other 12 (2.28%) patients died after the angio-embolization which were classified by: three for deep vein thrombosis; three for intra-cranic problems, four for comorbidities; two disseminated intravascular coagulation (Table 3). Only 63 (11.98%) patients underwent angio-embolization for control of bleeding and 3 recived a vena cava filter. The average amount of blood transfused was 8.3 IU (range 2–16 IU).

Average Days for the second surgery (range) was 8.4 days (range 7–12) and in all 406 (77.18%) cases underwent surgery of open reduction and internal fixation (ORIF) with

Table 3
Description of our results.

Parameters	Description
Moratlity	24 (4.56%) deaths during the permanence in hospital:
	12 (2.28%) cardiac and pressure shocks under angio-ambolization;
	12 (2.28%) after angio-ambolization:
	-3 for deep vein thrombosis;
	-3 intra-cranic problems;
	-4 for comorbilities;
	-2 disseminated intravascular coagulation.
Number of intervention of interventistic radiology	63 (11.98%) underwent angio-embolization
	3 recived a vena cava filter
Average days for the second surgery (range)	8.4 (7-12)
Number of open reduction and internal fixation (ORIF)	406 (77.18%)
Types of complications	24 (4.56%) orthopedics damage control complications
	16 (3.94%) early internal fixation complications
Orthopedics damage control complications	24 (5.91%) complication during ortophedics damage control:
	-10 decubitus (41.67%) patients (4 decubitus by pelvic belt 3 circumferential sheeting and 3 by rest in bed);
	-5 (20.83%) erroneous insertion of an C-clamp implant;
	-5(20.83%) pin tract infection in external fixation patients;
	-4(16.67%) external fixation's pin implant failure;
Early internal fixation complications	16 (3.94%) early internal fixation complications:
	-4 (25%) early wound infection ;
	-10 (62.5%) femur cutaneous nerve injury;
	-2 (12.5%) haematoma which needed exploration in patients.
Discharge of 502 alive patients	281 (55.98%) discharged at home
	221 (44.02%) discharged to rehabilitation facilities or extended care facilities

plates and wires (Table 3). Two types of complications were distinguished, damage control and early internal fixation complications (Table 3). A total of 24 (4.56%) complications were in damage control, the most frequent ones included decubitus in 10 (41.67%) patients (4 decubitus by pelvic belt, 3 by circumferential sheeting and 3 by rest in bed), erroneous insertion of an C-clamp implant in 5 (20.83%) and pin tract infection in external fixation in 5 (20.83%) patients and 4 (16.67%) external fixation's pin implant failure (Table 3). We had 16 early post-operative internal fixation complications requiring repeat surgery that were early wound infection in 4, femur cutaneous nerve injury in 10 and hematoma which needed exploration in 2 patients (Table 3). At the demission, 281 of 502 alive patients were able to be discharged home while the remaining 221 being transferred to various rehabilitation facilities or extended care facilities (Table 3).

4. Discussion

Fractures of the pelvic ring comprise about 2% of all fractures, but the incidence is increasing due to increasing numbers of high-speed vehicular crashes and suicide attempts[5]. Mortality associated with isolated pelvic injury, independent of severity, has been reported to be low (1%-2%)[5]. Among multiply injured victims of blunt trauma, however, almost 20% have injuries to the pelvic ring[5]. Upon arrival in the emergency department, patients should be resuscitated according to the guidelines of the Advanced Trauma Life Support Course of the American College of Surgeons' Committee on Trauma[4-6]. Hemodynamically unstable pelvic trauma is a major problem in trauma surgery and even in the most experienced trauma centers[4-6]. A long living debate in the literature, with plenty of classifications and protocols, has not still established the best treatment strategy for these patients. Although the source of bleeding is non-arterial in most cases, arterial injury can account for hemodynamic instability in 10%-20% of patients[5,7,8]. Various arteries that cross the pelvis, including the internal iliac, obturator, superior gluteal and pudendal arteries, have been found to be the cause of bleeding in these fractures[9]. More than 40% mortality rate reported in these patients indicates the relatively severe nature of the injury and its associated poor prognosis. Open surgical exploration of arterial bleeding is not recommended: access to the iliac arteries is difficult to gain, and disruption of the pelvic hematoma and consequential loss of tamponed effect can produce massive, uncontrollable and often fatal bleeding[10,11]. In emergency plain radiographs of the chest and pelvis must be obtained at this stage[5]. CT is undeniably the most accurate means to identify peritoneal and especially retroperitoneal injuries, but the CT suite is an unsafe environment for the unstable trauma patient. An essential consideration in resuscitating these patients is thermal control, with a strict avoidance of early hypothermia, which exacerbates traumatic coagulopathies[5]. What the orthopedic trauma surgeon must keep in mind in emergency when called to treat the injuries of the pelvic girdle? These are the questions that must be asked: is a hemodynamically

unstable fracture? Is it an intra-abdominal bleeding? Is this a biomechanically unstable fracture? We must remember injury severity score is the most important predictor in defining mortality in patients with pelvic fracture and not the type of pelvic instability[12]. The first aid born on the place of accident[4]. Basically, the principles of trauma management of multiply injured patients with life-threatening hemorrhage from mechanically unstable pelvic fractures are divided into two main time periods. On the one hand, there is the emergency stabilization of the pelvic ring as the most important goal within the acute period to control the bleeding, at least with extraperitoneal tamponed if necessary. On the other hand, once the hemorrhaging has been stopped, the "late" and definitive internal fracture stabilization of the pelvis should be performed depending on the fracture pattern[13]. If the term damage control comes from US Navy: "Capacity of a ship to absorb damage and maintain mission integrity", which is the right orthopedic device that answers the questions that must be asked prior to the orthopedic damage control in pelvic ring injuries? Circumferential pelvic sheeting provides patient comfort and noninvasive, rapid, and temporary pelvic ring stability. A bed sheet is readily available, inexpensive, easily applied around the pelvis, and disposable[14]. Circumferential pelvic belt compression by means of the pelvic sling is an effective, noninvasive, and safe stabilization approach that is well suited for emergent, temporary management of open-book pelvic fractures at the accident scene[15]. The limit of the principals is the duration: Let in the more than 72 h have a high risk of pressure sores. For this reason, if you need a long-term immobilization, the temporary garrison should be replaced as soon as possible by final external fixation[15]. Another limitation is the inability to dominate with these two devices, the serious biomechanical instability of the pelvis[15]. The conservative treatment is good choice only in very stable pelvic ring injures[1]. The pelvic packing is for patients who remain in extremis with a probable retroperitoneal cause in spite of aggressive resuscitative efforts should not be transported to a distant angiography suite, especially if delay is involved[16]. These are often patients at risk for abdominal compartment syndrome, and who therefore need an open peritoneal cavity for adequate cardiovascular physiologic support after surgery[16]. If we take into account that the pelvis and abdomen are a cylinder and the mathematical formula "V= ϖh/3(r1 2+r1 r2+ r2 r2)" to determine the loss of blood, we understand the need to use two types of devices: C-clamp or external fixation[17,18]. To deal with posteriorly unstable fractures, Ganz *et al.* developed a pelvic C-clamp, now available in most trauma units[17]. It acts like a simple carpenter's clamp and can exert transverse compression directly across the sacroiliac joint. Experimental data[17] have shown that an average compression force of 342 N can be applied to the area of this joint[5]. C-clamp application can not only be difficult but dangerous in cases of comminuted sacral fractures. Neurovascular injury can occur due to crushing of the sacrum. Marsh *et al.* have reported pelvic penetration of the stabilizing pins and over-compression of the clamps[19]. The prongs of the C-clamp can be misapplied and have been accidentally placed into the true pelvis through the greater sciatic notch[5]. The anterior pelvic external fixation frame (APEFF) can be applied in the trauma bay, intensive care unit or operating room in around 20-30 min, that is a great advance[5]. Immediate APEFF of an unstable pelvic injury has been the mainstay of acute stabilization for the past few decades[5]. A Lot of authors[4] reported in their paper the reduction of mortality rates from 22% to 8% by adding acute APEFF to their hospital resuscitation protocol. Based on their results, they concluded that skeletal stabilization of pelvic injury should be viewed as a part of resuscitation rather than reconstruction. Köhler *et al.*[20] and others authors[21-24] have also documented decreased transfusion needs and reduced mortality with the use of anterior external fixator. Therefore we have also recommended immediate application of external fixation for hemodynamically unstable patients, and consider it a life-saving procedure. Another advance of APEFF is the prophylactic stabilization in all patients demonstrating bony instability, as even those patients who are initially hemodynamically stable on presentation may decompensate later[4]. The anterior fixator is thought to contribute to hemostasis by maintaining a reduced pelvic volume, allowing tamponed, and by decreasing bony motion at the fracture site, allowing clots to stabilize[5]. The pelvic fractures most amenable to this form of treatment are the open book fracture, and the unstable shear type when combined with longitudinal traction[21-24]. According Kellam[23], lateral compression injuries incur fewer benefits from this method. We do not agree with Kellam, because we believe adding the assembly of the routine APEFF, pins with power trochanteric and bars in distraction/compression can dominate all vector forces on the different floors of the space they have created the pelvic instability (Example: Figure 3). Dickson and Matta have demonstrated worsening of posterior deformity in patients treated with APEFF and it can aggravate the posterior instability in an unstable fracture configuration[25]. The orthopedic damage control is a moment, the unstable fractures of the pelvis require ORIF[26]. We performed the ORIF at an average of 8.4 (range 7-12) weeks after the orthopedic damage control according the theory of second hit window[27]. All complications occurred after damage control or ORIF are common complications that can occur with the devices used in the treatment of pelvic ring injures[5,15,25,28].

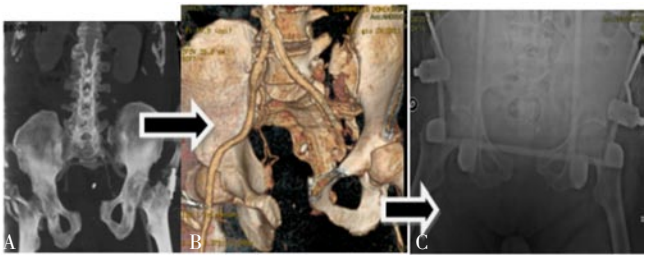

Figure 3. CT, 3D CT and XR of pelvic vertical shear instability.
A: CT; B: 3D CT; C: XR showing the reduction of pelvic vertical shear instability by APEFF.

The goal of treatment is to stabilize the initial vital signs, urinary function and protect the patient from infectious complications. A decision algorithm used in emergency helps manage hemodynamic instability. The procedures that allow legamentotaxis and osteotaxis and should be applied in an emergency until the patient's condition is stable enough for the surgical fixation final.

Conflict of interest statement

The authors report no conflict of interest.

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