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Intra-operative multi-dimensional fluoroscopy of guidepin placement prior to iliosacral screw fixation for posterior pelvic ring injuries and sacroiliac dislocation: an early case series

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Abstract

Purpose Traditional fluoroscopic techniques during percutaneous fixation of the posterior pelvic ring at times cannot adequately visualize errant or malpositioned iliosacral screws. Intra-operative fluoroscopic techniques have been advanced using multi-dimensional fluoroscopy to generate computed tomography-like images. This provides the surgeon not only the ability to assess iliosacral screw placement, but also the opportunity to assess reduction. We present a case series of four patients in which the Ziehm RFD multi-dimensional fluoroscopy was used to assess reduction and guidepin placement prior to definitive iliosacral screw fixation.

Methods Four patients at our university level 1 trauma center with posterior pelvic ring disruptions were treated with percutaneous iliosacral screw fixation. Traditional fluoroscopic techniques were used during guidepin placement. Multi-dimensional fluoroscopy was performed using the Ziehm RFD 3D to assess guidepin placement and reduction prior to definitive iliosacral screw fixation.

Results Our case series highlights two patients in which multi-dimensional fluoroscopy was utilized to ensure safe placement of iliosacral screws. In one of these two patients, a change was made after reviewing the imaging as a guidepin was found to be intruded into bilateral S2 neural tunnels. We also present two patient examples in which multidimensional fluoroscopy was used to assess reduction achieved by less invasive methods, precluding the need for direct visualization using more extensive open approaches.

Conclusions This retrospective case series demonstrates the direct impact that the Ziehm RFD 3D technology provides in surgical management of patients with complex posterior pelvic ring injuries.

Keywords Intra-operative · Fluoroscopy · Multidimensional · Iliosacral screw · Pelvic ring · Acetabulum

Introduction

Functional outcomes are optimized by accurate reduction and stable fixation in the operative treatment of unstable posterior pelvic ring disruptions [1]. The percutaneous treatment of sacral fractures, sacroiliac dislocations, and combination posterior pelvic injuries has evolved over the last three decades [1–3]. A recent prospective study comparing closed and open reduction techniques demonstrated superiority of closed techniques in achieving reduction of posterior pelvic ring disruptions [4]. Multi-planar intra-operative posterior pelvic fluoroscopy is used routinely to guide and assess both the reduction techniques and implant placements so as to avoid damaging various retroperitoneal structures and the sacral nerve roots [1, 5, 6]. These standard images include pelvic inlet, outlet, and true lateral sacral fluoroscopic views [1]. Post-operative pelvic computed tomography remains controversial due to the added radiation risk but allows the surgeon to best assess the reduction quality and implant location [2, 3]. Prior clinical series have demonstrated errant iliosacral screw rates of 2–15% identified solely on the post-operative CT scans [1, 7]. Screw-related neurological injuries have been reported at 7.7% [1, 8]. Iliosacral screw misplacement can ultimately lead to fixation failure as well.

A variety of navigation and imaging tools have attempted to increase implant placement accuracy and decrease radiation exposure [9–11]. In a recent meta-analysis, iliosacral screw

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malposition rates were no different when comparing 2D and 3D fluoroscopic navigation to conventional fluoroscopy [7]. CT-guided navigation has demonstrated the lowest rate of screw errors; however. reduction maneuvers are not possible since they alter the trajectory of the navigated screw [9–11]. The O-arm device (Medtronic, Colorado, USA) provides a version of intra-operative computed tomography but unfortunately requires specific patient positioning and risks radiation exposure [10]. For these and other reasons, widespread O-arm use for percutaneous fixation of the posterior pelvic ring has not been seen.

Intra-operative fluoroscopic techniques have been advanced recently by the Ziehm Vision RFD 3D unit (Ziehm, Nuremburg, Germany). This device is a standard C-arm fluoroscopy unit that also generates multi-dimensional axial, coronal, and sagittal reconstructed images by isometrically focusing on a fixed point and rotating in a 165-degree arc of motion with linear translation of 7.5° in opposite directions. Over the past 18 months, we have used this technology at our level-1 trauma center. We report four patients with pelvic traumatic injuries treated operatively using percutaneous techniques that were guided by and then assessed using the Ziehm rotational fluoroscopy device.

Patients and surgical technique

After institutional review board approval, a retrospective review of four adult patients with unstable posterior pelvic ring injuries treated operatively at a Level 1 trauma center was performed. Conventional pelvic inlet, outlet, and true lateral sacral fluoroscopic imaging were used to insert cannulated iliosacral screws. These four patients had rotational Ziehm multi-planar reconstructions performed intra-operatively after the guidepins were positioned and prior to the cannulated screw insertions.

Case example 1

A 62-year-old male pedestrian was struck by an automobile. He sustained multiple injuries including a flail chest, open fractures in his left foot, and spine fractures. His pelvic injuries included a displaced right-sided zone 2 complete sacral fracture and a displaced right anterior column acetabular fracture involving the iliac wing (Fig. 1a–b). He was resuscitated, placed into a pelvic binder, and had right sided distal femoral skeletal traction.

Intra-operatively, distal femoral skeletal traction was used to correct the posterior sacral displacement but not the fracture distraction. A 2.8-mm guidepin for the planned cannulated screws was placed within the upper sacral segment osseous pathway according to the pre-operative plan and the intra-operative imaging (Fig. 1c). Rotational fluoroscopy

was performed using the Ziehm. The reconstructed images demonstrated the guidepin to be well located and the sacral fracture was distracted (Fig. 1d–e). The sacral fracture was compressed and reduced using the partially threaded cannulated iliosacral lag screw. A trans-sacral screw at the second sacral segment supported the posterior fixation construct. Open reduction and internal fixation of the right acetabular fracture through an iliac window and percutaneous fixation of the left pubic ramus fracture were then performed (Fig. 1f).

Intra-operative axial, coronal, and sagittal imaging reconstructed from the rotational fluoroscopic images provided sufficient information regarding the closed reduction so that a percutaneous iliosacral lag screw could be used to reduce and stabilize the distracted posterior pelvic ring without an open, prone, posterior surgical approach to the sacrum. A post-operative pelvic CT scan confirmed the sacral and acetabular reductions and implant accuracy (Fig. 1g–h).

Case example 2

A 79-year-old male fell 12 ft from a roof and sustained a traumatic pelvic ring disruption. His posterior pelvic injury was classified as an H-type sacral fracture (Fig. 2a). He was initially hemodynamically unstable and required urgent exploratory laparotomy with splenectomy as well as angiographic embolization of the left internal iliac artery.

Once his overall condition was stabilized, he was taken for percutaneous management of his pelvic fractures. Using routine intra-operative fluoroscopy, a trans-sacral cannulated screw was inserted into the upper sacral segment. Then a similar trans-sacral guidepin was inserted through the second sacral segment. The guidepin was inadvertently located posteriorly and caudally within the second sacral segment osseous fixation pathway (Fig. 2b–c). Because of the wayward pin location, rotational fluoroscopy was performed. The reconstructed axial, coronal, and sagittal imaging revealed that the guidepin had violated the cortical margins of the sacral neural tunnels bilaterally (Fig. 2d). As a result of this imaging, a second guidepin was accurately located within the safe osseous fixation pathway of the second sacral segment so the cannulated trans-sacral screw could be safely inserted sparing the nerve root tunnels (Fig. 2e–f). In this patient, the reconstructed images from the rotational fluoroscopy confirmed the misplaced guidepin and allowed the definitive screw to be precisely located.

Case example 3

A 34-year-old male had numerous injuries after a high-speed motor vehicle collision. He had an unstable pelvic ring disruption with a right pubic ramus fracture, a right sacroiliac joint disruption, and a left sacral fracture. He was resuscitated and then underwent operative fixation of his pelvic ring injuries.
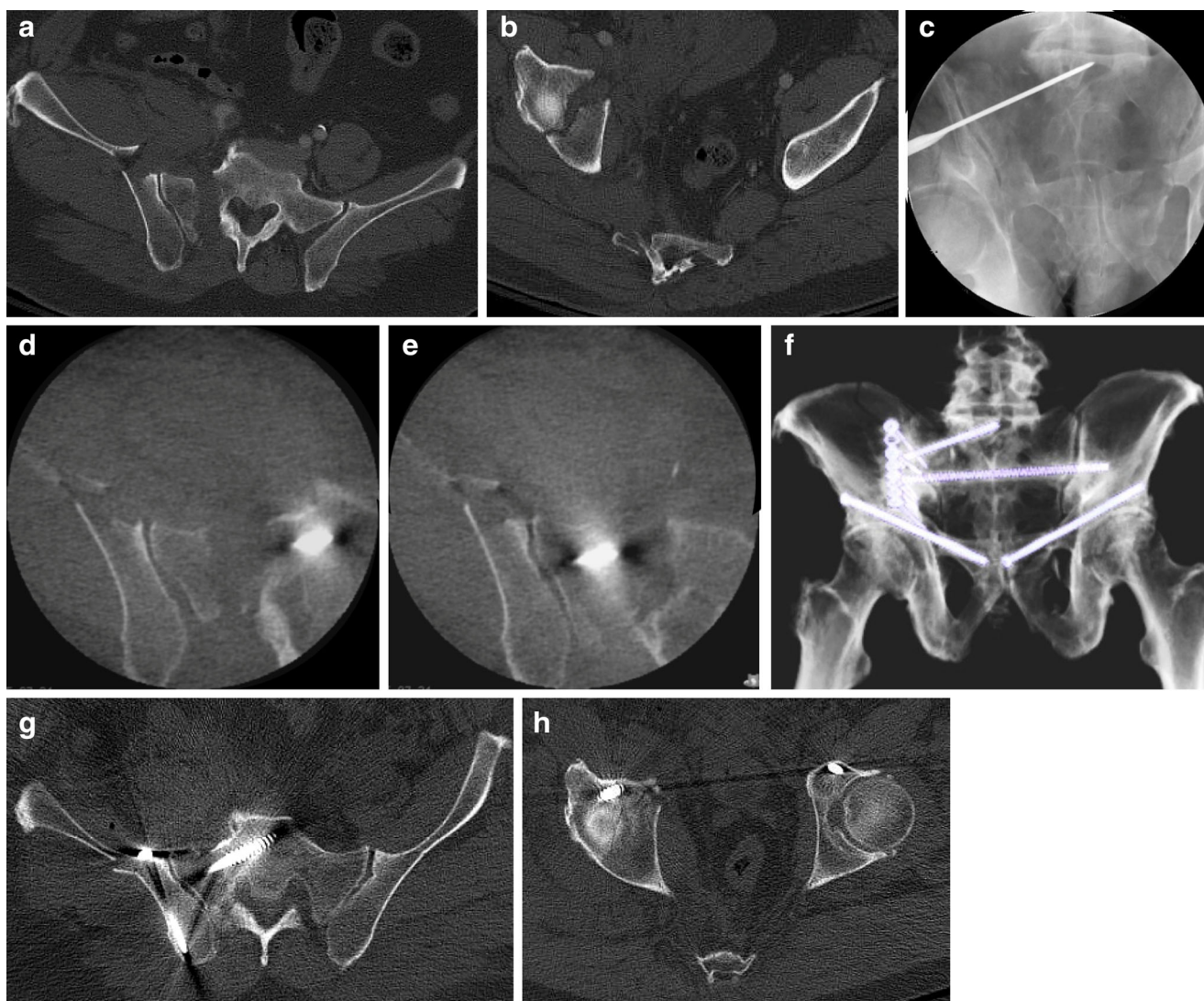
Fig. 1 Selected axial CT images demonstrating ipsilateral displaced sacral (a) and anterior (b) column acetabular fractures. c Intra-operative outlet demonstrating trajectory of the guidepin in the upper sacral segment. d–e Intra-operative axial imaging using multidimensional fluoroscopy demonstrating accurate pin placement in the upper sacral segment. f Surface rendered AP, selected axial cuts of the sacrum (g) and acetabulum (h)

The right pubic ramus fracture was symptomatic and unstable to compressive manual stress, but was minimally displaced without stress. The sacroiliac joint injury was symptomatic and displaced in distraction. The sacral fracture was complete and minimally displaced. Percutaneous screws were used to stabilize the pubic ramus, SI joint, and sacral injuries. During the placement of a cannulated trans-sacral iliosacral screw into the second sacral segment, there was intra-operative concern regarding the guidepin's location within the available osseous fixation pathway (Fig. 3a–b). The rotational fluoroscopy and reconstructed multi-planar images verified that the guidepin was accurately located (Fig. 3c). The second sacral segment trans-sacral screw was then inserted routinely (Fig. 3d). For this patient, the intra-operative rotational fluoroscopic reconstructed images were used to verify the guidepin's safe position.

Case example 4

A 16-year-old male was involved in a high-speed motorcycle crash and sustained a right acetabulum fracture with extension and displacement into the posterior ilium near the sacroiliac joint (Fig. 4a,b). His associated injuries included a right ankle fracture and Gustilo-Anderson type III-B open tibia and fibular fractures with compartment syndrome.

He was taken to the OR for emergent leg fasciotomies and external stabilization of his right lower extremity. Open reduction and internal fixation of the posterior portion of the acetabular fracture was performed through the lateral window of an ilioinguinal approach. A guidepin was then placed into the osseous corridor of the upper sacral segment (Fig. 4c). Rotational fluoroscopy was used and the reconstructed
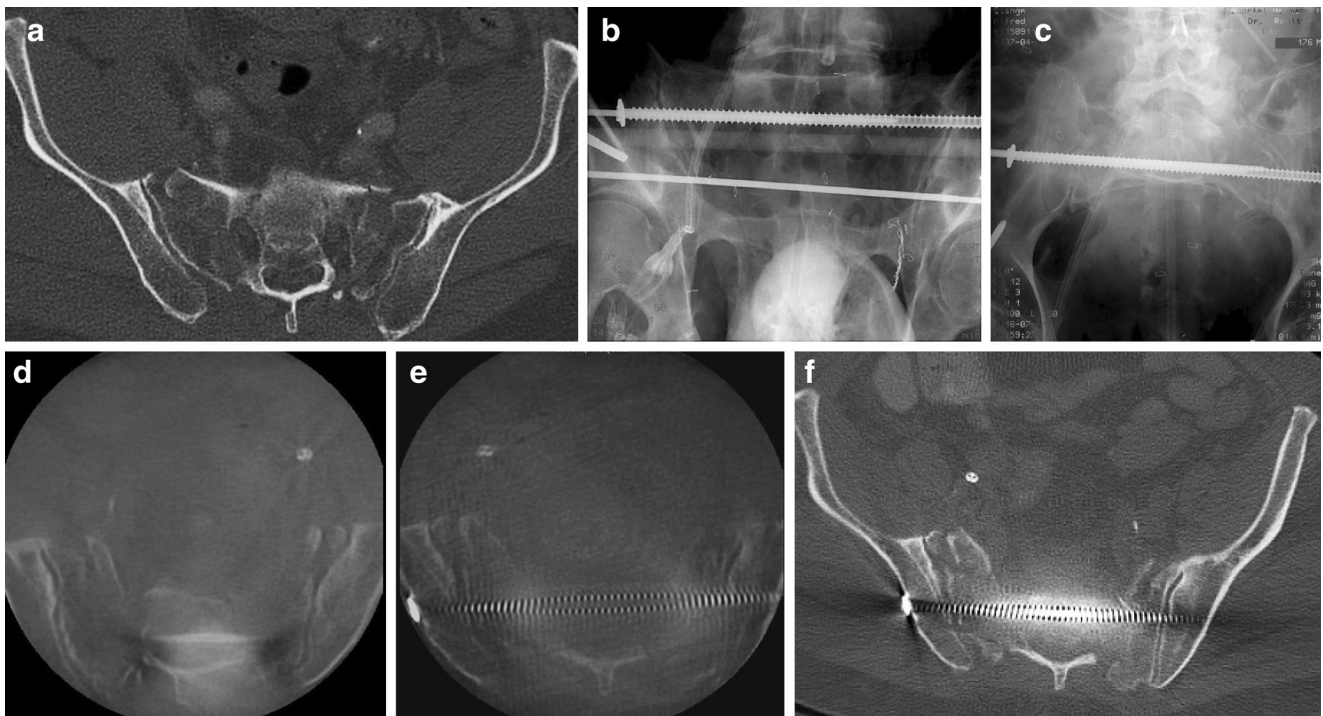
Fig. 2 a Axial CT image demonstrating bilateral sacral fractures. b–c Intra-operative AP (b) and inlet (c) and fluoroscopic images of the guidepin in the second sacral segment. d An intra-operative axial image reconstructed from rotational fluoroscopy showing the guidepin violating both neural tunnels in the second sacral segment. e An intra-operative reconstructed axial CT image showing the trans-sacral screw after guidepin correction. f A post-operative axial CT image with the trans-sacral screw in the second sacral segment

imaging demonstrated excellent alignment with persistent gapping at the fracture site (Fig. 4d). A partially threaded cannulated screw was applied to reduce the right posterior ilium (Fig. 4e). A second partially threaded cannulated screw was placed into the posterior portion of the acetabular fracture lateral to the sacroiliac joint. Open reduction and internal

Fig. 3 Intra-operative AP (a) and inlet (b) fluoroscopic images with the guidepin in the second sacral segment. c An intra-operative reconstructed axial CT image demonstrating safe placement of the guidepin in the second sacral segment. d A post-operative axial CT image of the trans-sacral screw in the second sacral segment
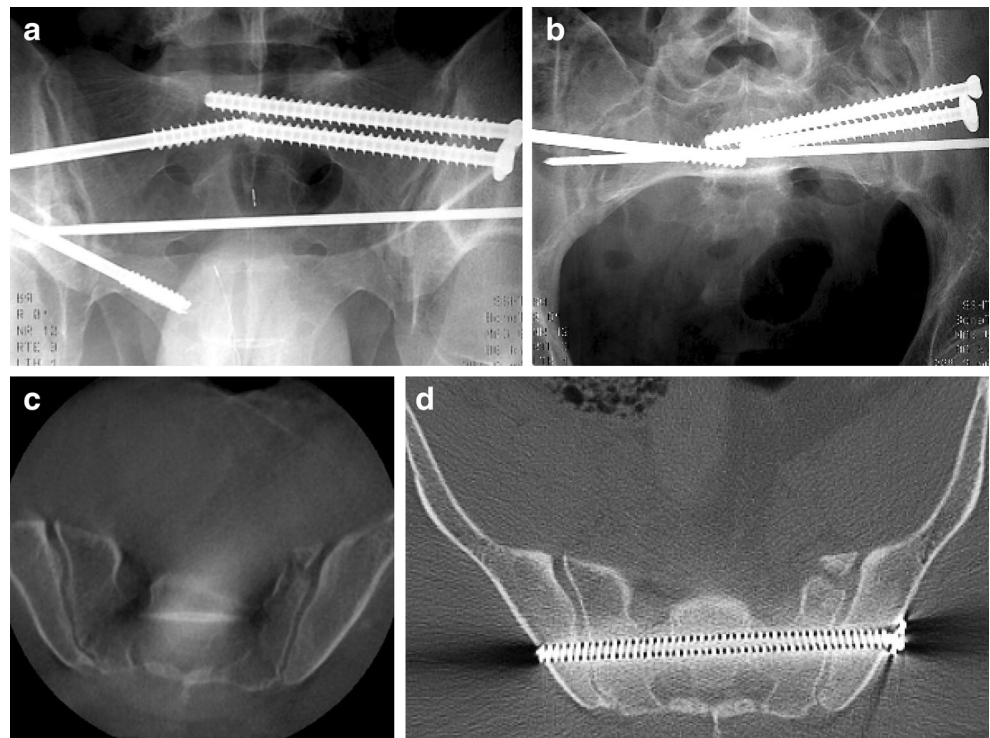
Fig. 4 a AP pelvis injury film. **b** Axial CT image demonstrating posterior iliac extension and displacement. **c** Intra-operative fluoroscopic inlet with clamp assisted reduction and guidepin placement. Intra-operative axial imaging using multidimensional fluoroscopy showing improved reduction and guidepin placement prior to (**d**) and after (**e**) screw compression. **f** Post-operative AP radiograph, axial CT images of the sacroiliac joint (**g**) and acetabular dome (**h**)

fixation of the acetabulum was completed three days later with staged anterior and then posterior approaches (Fig. 4f,h).

Intra-operative rotational fluoroscopy and reconstructed imaging allowed for evaluation of the reduction of the posterior ilium fracture without direct visualization through a prone paramedian approach.

Discussion

Precise assessment of reduction and implant placement using conventional fluoroscopy during iliosacral screw fixation can be difficult to achieve. Patient factors including body habitus, bowel gas, and residual contrast from prior imaging can make interpretation of implant position and injury reduction challenging [1]. Multi-planar fluoroscopic guidance and an understanding of pelvic and sacral anatomic variations are still required during placement of guidepins and screws during fixation [5, 6, 12]. However, two-dimensional fluoroscopy cannot fully assess accurate posterior ring reduction or iliosacral screw safety [3]. Post-operative CT scans have been used as the gold standard for post-operative evaluation of post-operative iliosacral screw position [2, 3].

Malpositioned iliosacral screws may traverse sacral foramina or the spinal canal potentially damaging sacral nerve roots, or lie anterior to the sacrum, with potential harm to the L4/L5

nerve roots, the pre-sacral vascular plexus, or other retroperitoneal structures. With traditional multi-planar, two-dimensional fluoroscopy, knowledge of these errors may not be known until (and if) a post-operative CT scan is complete. Revision, when indicated, requires a return to the operating room and additional anaesthesia.

The Ziehm RFD 3D allows for intra-operative CT-like axial, sagittal and coronal imaging. This novel technology provides the treating surgeon the ability to assess reduction and iliosacral screw placement. Furthermore, the placement and position of a guidepin may be assessed prior to placement of a cannulated screw. Using information provided by intra-operative multi-dimensional fluoroscopy, the surgeon has the opportunity to assess and correct malreduction and/or redirect fixation to a more accurate position in the same operative setting. The application of this imaging modality has not previously been described in the literature.

Our case series highlights two cases, patients 2 and 3, in which the Ziehm RFD 3D was used to assess guidepin placement prior to cannulated screw fixation. In one patient, a change was made when a guidepin was found to be intruded into bilateral S2 neural tunnels. This guidepin was replaced into the proper osseous corridor. The intra-operative CT reconstructions were able to ensure safe placement of iliosacral screws.

For combined, displaced injuries to the posterior pelvic ring and acetabulum, open reduction of the posterior pelvic ring may be indicated as malreduction of the posterior ring malpositions the ilium, potentially preventing accurate reduction of the articular surface of the acetabulum.

Some acetabular fractures extend posterior and cranial into the sacroiliac joint or posterior ilium. Extensile approaches to the acetabulum have been recommended for these patterns to allow visualization and accurate reduction of the posterior ilium that cannot be accessed through traditional ilioinguinal and Kocher-Langenbeck approaches [13–15].

Our series also highlights two cases, patient examples 1 and 4, where percutaneous methods with multi-dimensional fluoroscopy were chosen in lieu of additional, or more extensile open approaches for complex injuries to the pelvic ring and acetabulum. The Ziehm CT reconstructions provided sufficient intra-operative information to assess reduction achieved with percutaneous fixation.

Limitations to this case series include lack of long-term follow up and a comparison group of similar injuries where multi-dimensional fluoroscopy was not used. Still, there were benefits to each of these four patients using this imaging technology intra-operatively. We cannot quantify the long-term benefits based upon this small sample size. However, ensuring accurate and safe fixation, eliminating repeat trips to the operating room for revision, and less invasive surgical footprints should benefit patient outcomes in the future [1].

Conclusions

This retrospective case series demonstrates that the Ziehm RFD 3D technology directly impacted and changed the surgical management in four patients with complex injuries to the pelvic ring. The introduction of this imaging tool to our trauma center and its potential applications are incredibly powerful and present a step forward in intra-operative imaging.

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