

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

ScienceDirect

journal homepage: [www.elsevier.com/locate/radcr](http://www.elsevier.com/locate/radcr)

## Case Report

# The use of MRI digital subtraction technique in the diagnosis of traumatic pancreatic injury

Caroline Hubbard, BS, Madison R. Kocher, MD\*, Andrew D. Hardie, MD

Department of Radiology and Radiological Sciences, Medical University of South Carolina, 171 Ashley Avenue, Charleston, SC 29426, USA

### ARTICLE INFO

#### Article history:

Received 18 January 2019

Revised 28 February 2019

Accepted 2 March 2019

Available online 16 March 2019

#### Keywords:

Magnetic resonance imaging

Subtraction imaging

Traumatic pancreatic injury

### ABSTRACT

Traumatic pancreatic injuries are relatively uncommon in the setting of trauma, however, early detection of these injuries can alter patient management and overall prognosis. Computed tomography is the first line imaging modality in major trauma. Because failure to recognize pancreatic or main pancreatic duct injuries can lead to mismanagement, magnetic resonance imaging (MRI) can be a useful adjunct study in appropriate patients. In this report, we present a case in which MRI was used to diagnose traumatic avulsion and devascularization of the entire pancreas in a patient following a motor vehicle accident and we also include a review of the literature on this topic. It is our conclusion from this case report that MRI is the most effective imaging modality—specifically the subtraction post processing sequences—to evaluate severe pancreatic injury.

© 2019 The Authors. Published by Elsevier Inc. on behalf of University of Washington.

This is an open access article under the CC BY-NC-ND license.

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

## Introduction

Although traumatic pancreatic injuries are relatively rare, they can be associated with early morbidity and mortality and can have late complications from undetected pancreatic duct injury [1,2]. Although computed tomography (CT) is the current primary imaging modality in the setting of trauma because of its speed and spatial resolution, 20%–40% of pancreatic injuries can be missed on CT within the first 12 hours of injury which requires other imaging modalities such as magnetic resonance imaging (MRI) to fully assess the extent of injury [3]. Because of the longer imaging acquisition time of about 20–25 minutes, MRI is useful as an adjunct modality in traumas only in hemodynamically stable patients after the

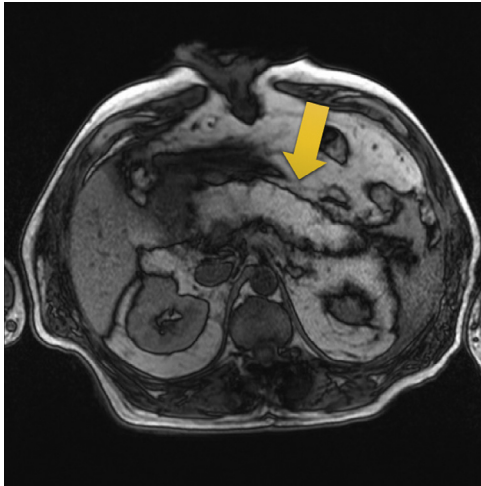
initial assessment and management has been performed. MRI allows more complete and accurate evaluation of the pancreatic duct and pancreatic soft tissues, particularly in the setting of necrosis or vascular compromise, which could alter the course of treatment for the patient. Subtraction imaging is a postprocessing technique that digitally subtracts a pre-contrast T1-weighted sequence from the identical sequence obtained after gadolinium contrast administration. This technique can better identify areas of hemorrhagic necrosis as any area of signal that is due to hemorrhage will subsequently be void of signal. Although this particular sequence has previously been used for the assessment and characterization of certain masses or cystic lesions, we advocate for its use in assessment of pancreatic vascular injury and necrosis. The following case and subsequent review of the

\* Corresponding author.

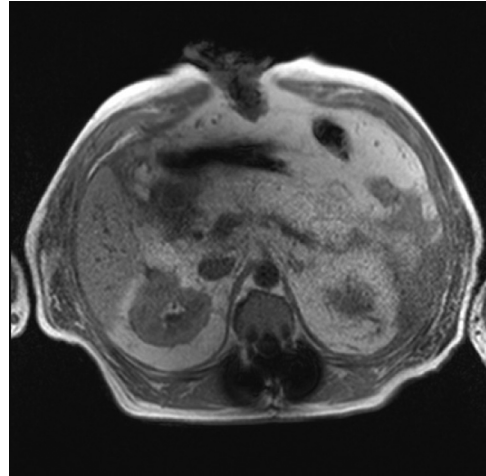
E-mail address: [Kocherm@musc.edu](mailto:Kocherm@musc.edu) (M.R. Kocher).

<https://doi.org/10.1016/j.radcr.2019.03.003>

1930-0433/© 2019 The Authors. Published by Elsevier Inc. on behalf of University of Washington. This is an open access article under the CC BY-NC-ND license. (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)



**Fig. 1 – T1-weighted out-of-phase sequence axial MRI. The pancreas is isointense to mildly hyperintense (yellow arrow) but entirely homogeneous.**



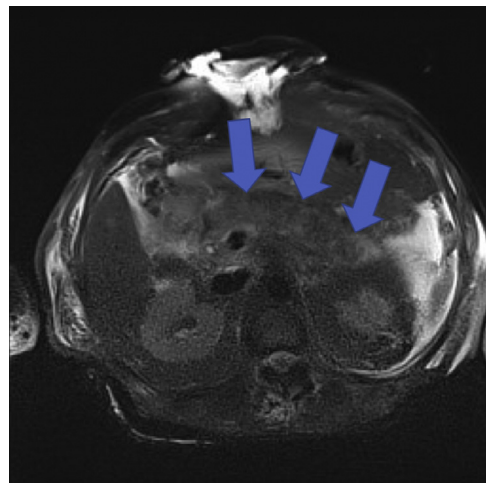
**Fig. 2 – T1-weighted in-phase sequence axial MRI. The pancreas is again homogeneous and isointense to mildly hyperintense in signal.**

literature discuss the important role that MRI digital subtraction technique plays in the diagnosis of hemorrhagic infarction of the pancreas in the setting of trauma.

### Case report

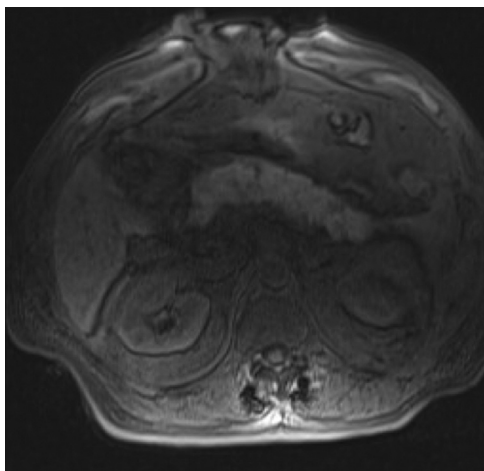
A 52-year-old male presented as a trauma transfer from an outside hospital following a motor vehicle accident. The patient was initially hemodynamically stable at the outside hospital and complained of upper mid epigastric abdominal pain, however, he quickly decompensated and had to be intubated. A CT scan with IV contrast was performed at the outside hospital demonstrating enhancement of the pancreatic head, extensive retroperitoneal injury, and inflammation with thickened walls of the duodenum as well as large volume intraperitoneal fluid. The patient was taken immediately to the operating room and an exploratory laparotomy was performed. Upon entering the abdominal cavity, a large volume of bloody ascites was evacuated and a grade 4 vs 5 pancreatic head injury (likely a contusion) extending into the body of the pancreas, a diffusely edematous duodenum, and an edematous gallbladder were discovered. The pancreatic duct was unable to be assessed at that time due to hemodynamic instability. Because of the extensive pancreatic injury and questionable integrity of the duct, the decision was made to obtain an MRI of the abdomen to assess the entire extent of the pancreatic duct prior to final washout and closure of the patient's abdomen. After the patient was hemodynamically stable following postoperative resuscitation, the MRI was obtained given its advantages in evaluating soft tissue structures when compared to CT.

On the T1-weighted out-of-phase sequence and in-phase sequence (Figs. 1 and 2), the pancreas appeared isointense to mildly hyperintense. There appeared to be heterogeneous areas of signal intensity within the pancreatic body and tail

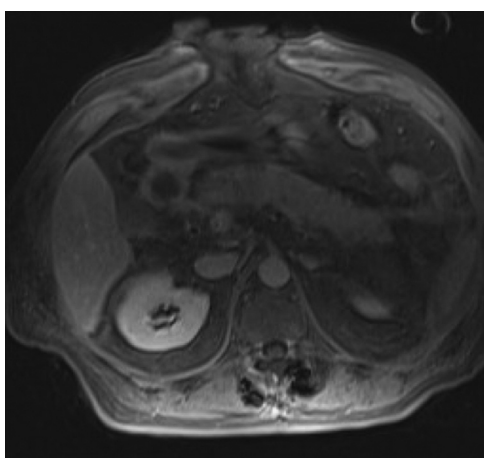


**Fig. 3 – T2-weighted sequence axial MRI. There are heterogeneous areas of signal intensity (blue arrows).**

on the T2-weighted sequences (Fig. 3). The pre- and post-contrast T1-weighted fat suppressed sequences showed what appeared to be intact, normal pancreatic architecture with mild diffuse high T1 signal within an overall normal appearing pancreatic parenchyma (Figs. 4 and 5). However, after digital subtraction was performed, the pancreas was completely void of signal with no parenchymal enhancement evident (Fig. 6). This correlated with the apparent diffusion coefficient map demonstrating diffuse restricted diffusion (Fig. 7), which results from the inability of water particles to freely move within the necrotic tissue. Therefore, the operative findings were correlated with the lack of enhancement seen in the digitally subtracted MRI to conclude that this particular patient's infarcted pancreatic tissue was the result of hemorrhage and vascular injury secondary to the trauma he



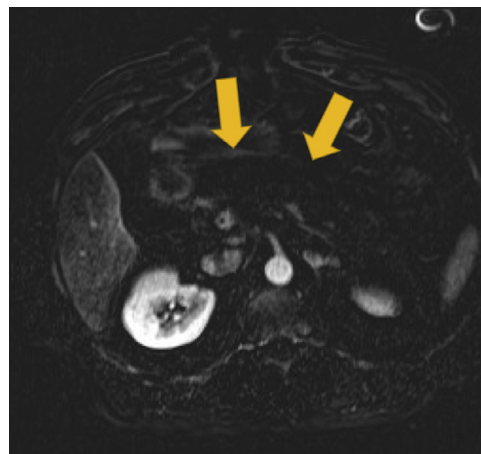
**Fig. 4 – T1-weighted fat suppressed precontrast axial MRI. The pancreatic architecture appears intact with mild diffuse increased T1 signal within the pancreatic tissue.**



**Fig. 5 – T1-weighted fat suppressed contrast-enhanced axial MRI. Pancreatic architecture is preserved with what appears to be normal parenchymal enhancement.**

sustained. Given the imaging findings, which revealed hemorrhagic infarction of the entire pancreas without any residual pancreatic enhancement, the management of this patient's injuries was significantly altered.

The patient received a splenectomy due to a splenic laceration he maintained during the accident and had multiple drains placed for the developing acute necrotic collections around his pancreas. Because it was revealed on MRI that the entire pancreas was hemorrhagically infarcted, there was no attempt at necrosectomy or surgical revision of the pancreatic duct, and sequential drains were placed to manage the acute necrotic collections as they developed. He remained in the intensive care unit for 4 weeks due to hemodynamic instability. A gastrojejunostomy tube was placed for nutrition, and he was finally discharged on hospital day 47.

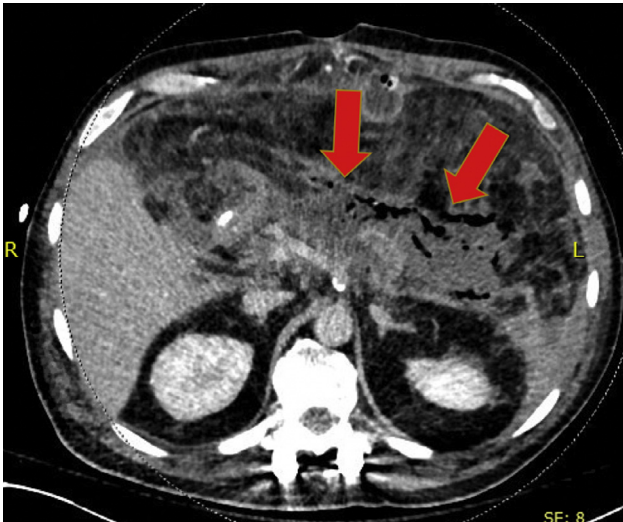


**Fig. 6 – Digital subtraction post processing axial MRI. No pancreatic parenchymal enhancement is evident, indicating diffuse infarction of the pancreas. The increased signal present on the T1-weighted nonsubtracted fat suppressed sequence is the result of hemorrhage. There is lack of parenchymal enhancement on the subtracted images, consistent with hemorrhagic infarction.**

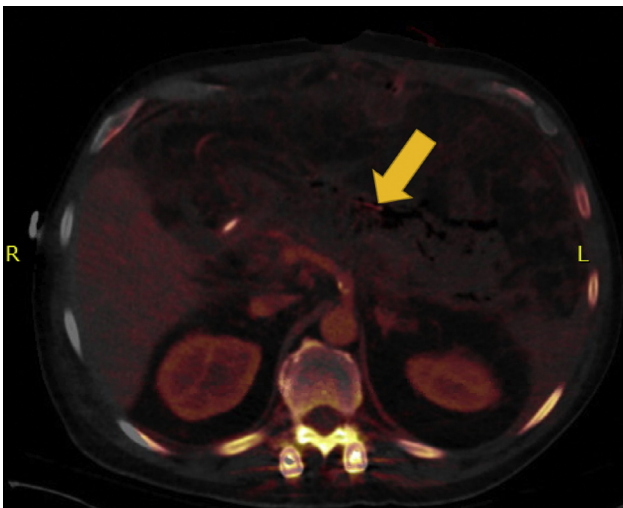


**Fig. 7 – Apparent diffusion coefficient map sequence axial MRI. There is low signal in the pancreatic body and tail, indicating restricted diffusion.**

Three weeks later after the initial trauma, a CT of the abdomen and pelvis was obtained with IV contrast that demonstrated extensive pancreatic necrosis (Fig. 8a). Additionally, there was no enhancing pancreas, as confirmed with Dual Energy CT (DECT) iodine map (Fig. 8b). Follow-up CT scan of the abdomen and pelvis with IV contrast was then obtained 2 months following the initial trauma, which demonstrated continued evolution of the necrotic pancreatitis (Fig. 9a). DECT iodine mapping demonstrated possible minimal enhancement at the uncinata process of the pancreas with no other residual enhancement of the pancreas (Fig. 9b).

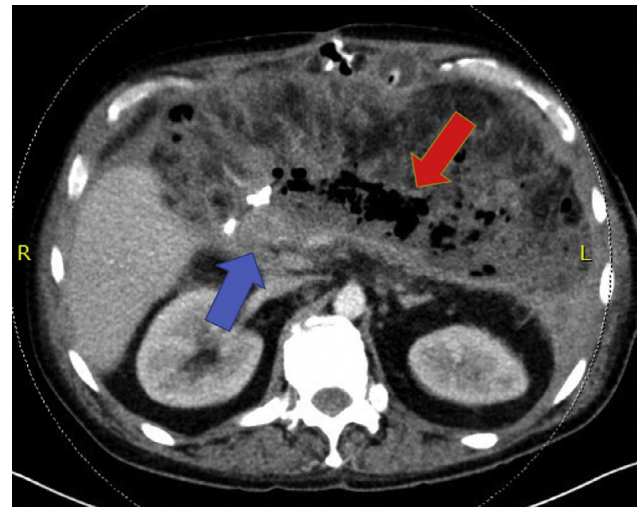


(a)

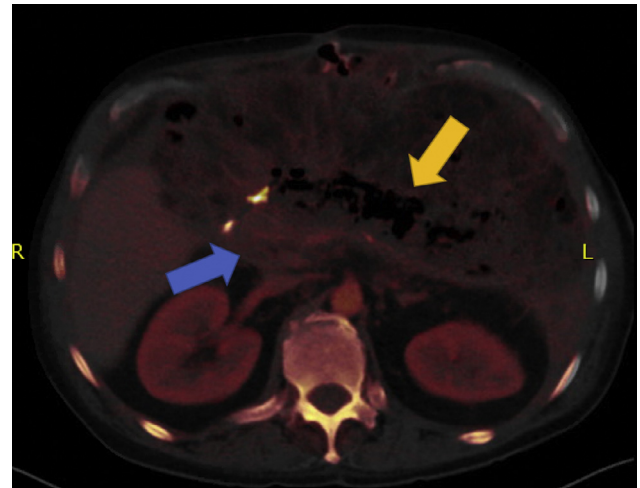


(b)

**Fig. 8 – (a):** Axial slice from portal venous phase of CT abdomen and pelvis obtained 3 weeks after the initial trauma demonstrates extensive pancreatic necrosis (red arrows) with a surrounding acute necrotic collection containing gas and fluid. A surgical drain is partially visualized within the collection. **(b):** Dual Energy CT (DECT) iodine map axial image from the same CT abdomen and pelvis with IV contrast 3 weeks after the initial trauma demonstrates no enhancing pancreas (yellow arrow) with multiple acute necrotic collections around the pancreatic bed.



(a)



(b)

**Fig. 9 – (a):** Axial slice from portal venous phase of CT abdomen and pelvis obtained 2 months after the initial trauma demonstrates continued evolution of the necrotic pancreatitis with increased gas and fluid collection centered in the pancreatic bed (red arrow) and questionable enhancement at the uncinate process (blue arrow). **(b):** DECT iodine map axial image from the same CT abdomen and pelvis with IV contrast 2 months after the initial trauma again demonstrates continued evolution of the necrotic pancreatitis with no enhancement in the pancreatic bed (yellow arrow) and minimal residual enhancement in the uncinate process (blue arrow).

## Discussion and review of the literature

### Overview of pancreatic injuries

Traumatic injury to the pancreas is relatively rare; in the adult population, pancreatic injury has been estimated to occur in 4% of abdominal injuries [3] with reported ranges of 0.2%-12%

[4]. The incidence of pancreatic injury is estimated to be 0.4% in both pediatric and adult traumas [5]. The rate of pediatric pancreatic injury within the specific setting of abdominal injury has been reported to be 0.6% by a study based on the National Trauma Data Bank, with rates closer to 10% in the setting of blunt abdominal trauma [5]. Due to the positioning of the pancreas anterior to the vertebral column, pancreatic injuries are most commonly seen in the setting of high impact

blunt trauma in adults such as motor vehicle crashes [3,4]. The majority of pancreatic injuries occur in the body of the pancreas with equal distribution of the remainder of injuries throughout the head, neck, and tail [1]. The close vascular associations with the pancreas are the root of early morbidity and mortality while later complications arise as a result of pancreatic duct injury [1]. A variety of complications can occur in the setting of injury to the pancreatic duct secondary to leakage of pancreatic enzymes including abscess formation, inflammation, and sepsis [1]. Duct injury is managed with stent placement either surgically or endoscopically depending on the clinical situation. Diagnosis of pancreatic duct injury is crucial for proper surgical management as injury to the main pancreatic duct is the major prognostic factor following trauma to the pancreas with such injuries reported to occur in 15% of cases [2,3]. Delayed diagnosis of pancreatic injury in the setting of a multiorgan trauma predisposes the patient to significant complications and the presence or absence of duct injury contributes to the decision whether to manage the patient operatively or nonoperatively [2].

### **Clinical diagnosis of pancreatic injuries**

Diagnosis of pancreatic injury poses many issues for the clinician as signs of injury are often subtle in the setting of multiorgan trauma. Clinical findings are often nonspecific and may include epigastric tenderness, Grey Turner's sign, and Cullen's sign. Laboratory values typically associated with pancreatic dysfunction, such as amylase and lipase elevations, are of limited clinical utility as the alterations in the values are often variable in the acute setting [3]. Pancreatic injuries are typically graded according to the American Association for the Surgery of Trauma which is utilized to guide operative management of pancreatic trauma, although it has no prognostic value [6]. Endoscopic retrograde cholangiopancreatography (ERCP) plays a potential role in managing patients in which a ductal injury has been identified on MRI or CT or if there is high clinical evidence of such injury [1]. ERCP assists in determining the role of surgery while also enabling the clinician to perform therapeutic interventions, such as stent placement. However, despite its advantage of direct clinical examination of ductal integrity, ERCP is invasive and has its own set of complications; thus, its use is often not appropriate or timely in the acute setting. Another disadvantage is that it does not allow any assessment of the surrounding pancreatic parenchyma that can be done in cross-sectional imaging. The clinician must have a high index of clinical suspicion and appropriate imaging techniques to effectively identify and grade pancreatic trauma.

### **CT and pancreatic injuries**

In the setting of trauma, CT is the imaging test of choice in hemodynamically stable patients to assess the abdomen and pelvis quickly. Pancreatic focal enlargement, laceration, and transection are considered direct signs of pancreatic injury on CT while useful secondary signs that are suggestive of pancreatic injury include peripancreatic fat stranding, injuries of closely associated structures, and presence of fluid or hemorrhage [1]. Acute hemorrhage is hyperattenuating on

CT and expected to continue to enlarge when viewed with multiphasic imaging [4]. Focal collections of hemorrhage, such as pseudoaneurysms, will be hyperattenuating then subsequently wash out in delayed phases while pancreatic contusions are evidenced by focal hypoattenuating areas [4]. While CT is currently the mainstay imaging technique in the setting of abdominal trauma, there are important limitations that must be considered by the clinician. As noted by Lahiri et al, previous studies have reported that 20%-40% of pancreatic injuries are missed on CT within the first 12 hours of injury [3]. In addition, while CT effectively evaluates the pancreatic parenchyma, it is limited in its ability to assess the major prognostic factor for pancreatic trauma—the main pancreatic duct.

DECT is an advanced CT technique which is able to specifically identify iodine from intravenous contrast administration, eliminating the contribution of potentially high Hounsfield Unit density noniodine components to the CT images. Interestingly, this is ultimately similar to MRI subtraction technique in practice, as both are better able to provide images which allow the reader to better interpret which tissues are in fact enhancing and thus vascularized. DECT has advantages in differentiating enhancement vs hemorrhage and it may require less time than digital subtraction MRI depending on a particular institution's protocol. However, the use of DECT in trauma has not been extensively researched primarily because an additional 5-10 minutes are typically required to create the postprocessed images [7]. In addition, it is likely that the sensitivity for small amounts of contrast with DECT would be less than subtraction MRI. In reference to pancreatic injury, one must consider the ability of DECT to effectively evaluate the pancreas. Most trauma imaging protocols do not scan the patient at the time of peak enhancement of the pancreatic parenchyma, as this phase occurs earlier in comparison to other abdominal viscera [7]. DECT may improve the visualization of abdominal organ injuries when compared to standard trauma protocol imaging, but its pancreatic duct evaluation is a limiting factor that must be considered in cases of pancreatic injury and the subsequent potential need for additional imaging or interpretation time.

### **MRI and pancreatic injuries**

MRI is a beneficial technique for further characterization of pancreatic architecture and pathology. T1-weighted gradient-echo, axial and coronal T2 weighted turbo spin echo (or a TSE variant) sequences, 2D/3D magnetic resonance cholangiopancreatography (MRCP), and 3D T1 echo before and after gadolinium contrast are the usual sequences obtained to fully evaluate the pancreas and ductal system [8]. Contrast enhancement enables acquisition of early arterial phase, pancreatic parenchymal phase, and portal venous phase sequences [9]. Contrast-enhanced fat suppressed T1-weighted sequences provide sensitive evaluation of hemorrhage, which will be represented by an area of high signal intensity. In contrast, due to changes in the hemoglobin content and form, chronic hemorrhage appears hypointense on both T1 and T2 sequences [9]. The major advantages of MRI in the setting of pancreatic trauma lie in its soft tissue and pancreatic duct evaluation, which is one of the major limitations of CT [2]. In

the prospective study by Panda et al, reader confidence was improved by 58.8% with MRI due to greater delineation of pancreatic laceration extent, identification of injured vs non-injured pancreatic tissue, and visualization of the anatomy and structural integrity of the pancreatic duct [10]. These advantages are likely the result of better soft tissue visualization and contrast on MRI when compared to CT. In addition, MRI allows clinicians to follow changes in injury over time without radiation burden to the patient while overcoming the short-comings of CT in terms of pancreatic duct evaluation, a key component for guiding management.

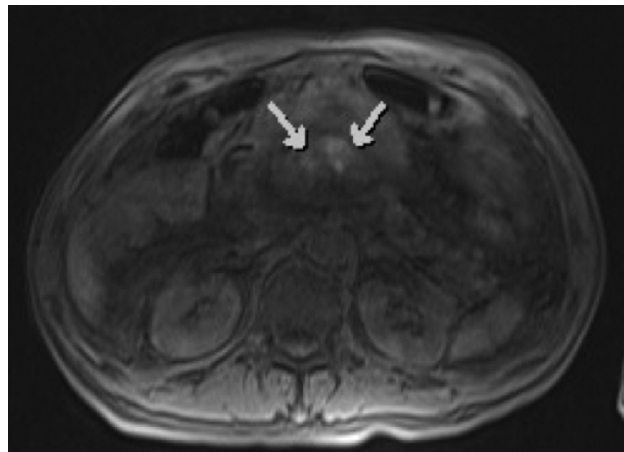
MRCP is less invasive than ERCP and is a useful imaging technique in evaluating both the pancreas and its surrounding structures, especially the liver [1,4]. Rekhi et al described the use of MRCP as a next imaging modality of choice following the initial trauma CT if question still surrounds the integrity of the pancreatic duct [4]. In addition, IV secretin can be used in the setting of MRCP to effectively outline the physiology and functional anatomy of the main pancreatic duct while also highlighting upstream injuries that may not be as easily identified by ERCP [4]. MRCP can be a beneficial additional technique to aid clinicians in effectively managing pancreatic injury, although it does not play a role in the acute trauma setting.

#### Overview of subtraction imaging

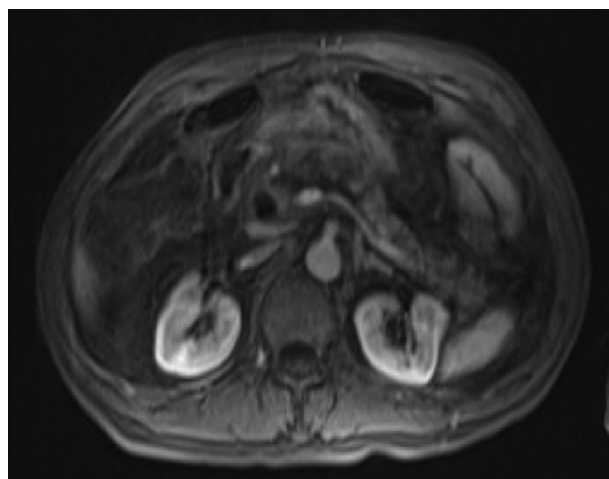
Subtraction imaging is a postprocessing technique that digitally subtracts a precontrast T1-weighted sequence from the identical sequence obtained after gadolinium contrast administration. Therefore, the remaining signal on the digitally subtracted image is due to enhancement alone and not native T1 signal [11]. In the setting of hemorrhage, intracellular and extracellular methemoglobin creates areas of high signal on unenhanced T1-weighted sequences [11] and administration of contrast can obscure detection of these areas of enhancement on T1-weighted sequences [12]. If digital subtraction is then performed, any signal that is due to hemorrhage will be void of signal. This technique enables more precise evaluation of clinically significant enhancement areas, particularly within a mass or cystic lesion [11].

At centers with MRI, postprocessing techniques such as digital subtraction can be readily performed and have been widely utilized previously in breast imaging and MR angiography [11]. Many centers employ digital subtraction as a standard component of particular imaging protocols. In order for this technique to be successfully performed, patient position and breath-hold maneuvers must remain constant in addition to the image receiver gain and scale factor for both the unenhanced and enhanced sequences [11,12]. MRI is not utilized in the initial assessment of acute trauma given the additional scan time; however, as demonstrated by this case, it is an important adjunct to fully assess the extent of injuries in hemodynamically stable patients when questions continue to surround the clinical picture.

Digital subtraction technique in MRI is especially helpful in cases of pancreatic necrosis, such as in the above case report, because all pancreatic necrosis has some level of hemorrhage due to venous oozing. Because this adds to the T1-weighted signal intensity of the pancreas, the higher inherent T1 signal



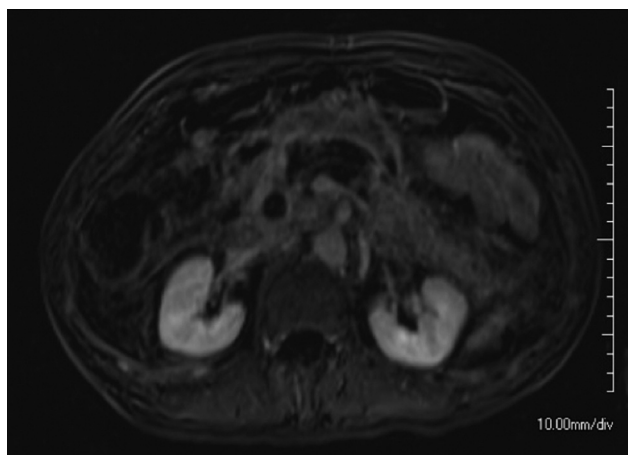
**Fig. 10 – (Correlative case) T1-weighted fat-suppressed precontrast axial MRI on a different patient. There is heterogeneously increased signal within the pancreatic tissue.**



**Fig. 11 – (Correlative case) T1-weighted fat suppressed contrast-enhanced axial MRI. Pancreatic architecture appears to be preserved with presumably normal parenchymal enhancement.**

can be mistaken for contrast enhancement of postcontrast gradient echo images. Subtraction imaging technique would be critical in this situation as it can negate this contribution of hemorrhage to the T1 signal of the pancreas.

In a corollary case, a different patient underwent MRI due to severe abdominal pain and concern for pancreatitis that was difficult to appreciate on CT. The initial T1-weighted precontrast image demonstrates heterogeneously increased signal within the pancreatic parenchyma, while the T1-weighted contrast-enhanced image demonstrates what appears to be normal pancreatic enhancement (Figs. 10 and 11). Without the use of postprocessing digital subtraction technique, it would be impossible to tell if this increased signal was due to blood products or to contrast, however, with the use of this technique, the subsequent signal void in the pancreatic region



**Fig. 12 – (Correlative case) Digital subtraction post processing sequence axial MRI on a different patient. This image demonstrates subsequent signal void and therefore no contrast enhancement, indicating that there is hemorrhagic necrosis of the neck of the pancreas.**

demonstrates there is no enhancement and that there is hemorrhagic necrosis of the neck of the pancreas (Fig. 12).

#### *Application of subtraction imaging to our case*

MRI using a multichannel phased array coil with and without contrast was performed on this presented patient in our above case report given the uncertain clinical scenario upon transfer in the setting of a known trauma. On initial review of the pre- and postcontrast nonsubtracted fat suppressed T1 sequences, the pancreatic architecture appeared to be intact which lowered clinical suspicion for pancreatic injury. However, the addition of digital subtraction postprocessing sequences drastically changed the management of this patient to medical management and sequential drain placement as it demonstrated a pancreas completely void of signal, consistent with hemorrhagic infarction, and therefore nonsurgical. As confirmed by this case, digital subtraction technique is a neces-

sary adjunct in the accurate evaluation of the abdominal viscera with MRI that can drastically alter patient management.

#### REFERENCES

- [1] Gupta A, Stuhlfaut JW, Fleming KW, Lucey BC, Soto JA. Blunt trauma of the pancreas and biliary tract: a multimodality imaging approach to diagnosis. *Radiographics* 2004;24(5):1381–95.
- [2] Bradley EL 3rd, Young PR Jr, Chang MC, Allen JE, Baker CC, Meredith W, et al. Diagnosis and initial management of blunt pancreatic trauma: guidelines from a multiinstitutional review. *Ann Surg* 1998;227(6):861–9.
- [3] Lahiri R, Bhattacharya S. Pancreatic trauma. *Ann R Coll Surg Engl* 2013;95(4):241–5.
- [4] Rekhi S, Anderson SW, Rhea JT, Soto JA. Imaging of blunt pancreatic trauma. *Emerg Radiol* 2010;17(1):13–19.
- [5] Englum BR, Gulack BC, Rice HE, Scarborough JE, Adibe OO. Management of blunt pancreatic trauma in children: review of the National Trauma Data Bank. *J Pediatr Surg* 2016;51(9):1526–31.
- [6] Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Champion HR, Gennarelli TA, et al. Organ injury scaling, II: pancreas, duodenum, small bowel, colon, and rectum. *J Trauma* 1990;30(11):1427–9.
- [7] Wortman JR, Uyeda JW, Fulwadhva UP, Sodickson AD. Dual-energy CT for abdominal and pelvic trauma. *Radiographics* 2018;38(2):586–602.
- [8] Sandrasegaran K, Lin C, Akisik FM, Tann M. State-of-the-art pancreatic MRI. *AJR Am J Roentgenol* 2010;195(1):42–53.
- [9] Sahni VA, Mortelet KJ. The bloody pancreas: MDCT and MRI features of hypervascular and hemorrhagic pancreatic conditions. *AJR Am J Roentgenol* 2009;192(4):923–35.
- [10] Panda A, Kumar A, Gamanagatti S, Bhalla AS, Sharma R, Kumar S, et al. Evaluation of diagnostic utility of multidetector computed tomography and magnetic resonance imaging in blunt pancreatic trauma: a prospective study. *Acta Radiol* 2015;56(4):387–96.
- [11] Newatia A, Khatri G, Friedman B, Hines J. Subtraction imaging: applications for nonvascular abdominal MRI. *AJR Am J Roentgenol* 2007;188(4):1018–25.
- [12] Lee VS, Flyer MA, Weinreb JC, Krinsky GA, Rofsky NM. Image subtraction in gadolinium-enhanced MR imaging. *AJR Am J Roentgenol* 1996;167(6):1427–32.