Original Article

The application value of computed tomography and magnetic resonance imaging sinography/fistulography in evaluating chronic wounds: a prospective study

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Background: Chronic wounds are a worldwide health problem, with traditional imaging techniques failing in their accurate evaluation. Therefore, an effective imaging evaluation method is needed for the diagnosis and treatment or chronic wounds. This study is to investigate the application value of computed tomography (CT) and magnetic resonance imaging (MRI) sinography/fistulography in assessing the morphology and deep features of chronic wounds.

Methods: We prospectively enrolled 43 chronic wounds patients who received both CT and MRI sinography/fistulography. The morphology and deep features of chronic wound on CT and MRI images were independently evaluated by 2 experienced radiologists. Kappa value and intraclass correlation coefficient (ICC) were calculated to evaluate the interobserver agreement and the consistency between CT and MRI sinography/fistulography in assessing the shape, number of branches, and involvement of body cavity and bones of chronic wounds.

Results: There were substantial to almost perfect interobserver agreements for both CT and MRI sinography/fistulography in evaluating the morphology and deep features of chronic wounds. The consistency between CT and MRI was almost perfect for the 2 readers in evaluating the shape (reader 1, kappa value =1.000; reader 2, kappa value =0.932) and the number of branches [reader 1, ICC =0.951 (95% confidence interval: 0.909–0.973, $P<0.001$); reader 2, ICC =0.874 (95% confidence interval: 0.768–0.932, $P<0.001$)], and substantial to almost perfect when evaluating the involvement of body cavity (reader 1, kappa value =0.728; reader 2, kappa value =0.775) and bones (reader 1, kappa value =0.659; reader 2, kappa value =0.860).

Conclusions: There was good interobserver agreement and consistency between CT and MRI sinography/fistulography in evaluating the morphology and deep features of chronic wounds.

Keywords: Chronic wounds; computed tomography (CT); magnetic resonance imaging (MRI); sinography; fistulography

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Introduction

Chronic wounds are wounds which fail to progress through the normal phases of wound healing or restore anatomic and functional integrity within 6 weeks (1,2). It has been reported that chronic wounds affect 1–2% of the global population (3). The treatment and health care provision for chronic wounds have been a worldwide problem and cause increasing economic burden to patients and their governments (4,5).

The majority of chronic wounds manifest as a tract or cavity with a small external opening, substantial depth, and sometimes multiple branches. They can also extend to the bone, body cavity, or another epithelial surface to form fistula (6). The complicated morphology and deep features of chronic wounds cause significant difficulties in diagnosis and treatment, therefore effective imaging evaluation is necessary. However, traditional imaging techniques such as X-ray sinography/fistulography, ultrasound, and laser surface scanning imaging are unable to accurately evaluate the morphology and deep features of chronic wounds (7).

Previous studies have reported the application of computed tomography (CT) and magnetic resonance imaging (MRI) in imaging evaluation of chronic wounds (8-12); CT scan relay high anatomic detail of chronic wounds and assess surrounding bone destruction (3), and MRI has high resolution and sensitivity to soft tissue without ionizing radiation. It is possible to combine CT and MRI with sinography/fistulography, which allows for visualization of internal features of the sinus/fistula by instilling contrast agent into the external opening (9). However, CT and MRI sinography/fistulography have not yet been widely applied and recommended as routine imaging techniques for chronic wounds, which is due to the complicated procedures, inevitable incompletely filling of contrast agent and requirement for highly integrated team of radiologists and surgeons. In this study, we investigated the application value of CT and MRI sinography/fistulography in assessing the morphology and deep features of chronic wounds. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/apm-21-2342).

Methods

Study population

All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). This prospective study was approved by the institutional review board of Ruijin Hospital, Shanghai Jiao Tong University School of Medicine (No. 2018-27), and written informed consent was provided by each patient before undergoing CT and MRI scanning. Patients with chronic wounds (failure to heal in 6 weeks) were enrolled in Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, China from January 2019 to April 2020. Exclusion criteria were standard safety contraindications to CT and MRI scanning. Besides, patients with insufficient contrast agent filling, incomplete imaging sequences, and lack of clinical data were excluded for images analysis (*Figure 1*). The final study population included a total of 43 patients [21 men (48.8%) and 22 women (51.2%), median age, 65 years (range, 18–94 years)].

CT and MRI Examination

Before imaging examinations, surgeons performed endoscopy to clean chronic wounds to ensure that there was no foreign matter or pus affecting the imaging examinations. Participants took a supine, lateral, or prone position with the external opening upward and contrast agent was instilled into the external opening until it spilled over to fill the chronic wounds as full as possible. The instillation of contrast agent complied with the aseptic manipulation. Both CT and MRI scanning were performed on patients, and the time interval between CT and MRI scanning was less than a week. The CT scan was performed on a 256-slice CT scanner (uCT 760, United Imaging, Shanghai, China). The scan parameters were as follows: 120 kv, 300 mAs, and section thickness of 1.0 mm. The contrast agent for CT sinography/fistulography was 10% iomeprol (Iomeron, Bracco, Milan, Italy). The MRI scans were performed on a 1.5 T scanner (Magnetom Aera; Siemens Healthcare, Erlangen, Germany) using a 6-channel body phased array coil. The MR scanning sequences included axial T1-weighted (T1w), axial fat-saturated T1w, coronal or sagittal fat-saturated T1w, and axial fat-saturated T2-weighted (T2w). Parameters of the sequences are shown in *Table 1*. The contrast agent for MRI sinography/fistulography was 0.2 mmol/L gadopentetic acid dimeglumine (Magnevist, Bayer, Barmen, Germany). Multiplanar reconstruction (MPR) and maximum intensity projection (MIP) of CT images and axial T1w MR images were performed to achieve 3-dimensional (3D) visualization of chronic wounds. After scanning, surgeons cleaned the chronic wounds and changed the dressing to avoid infection

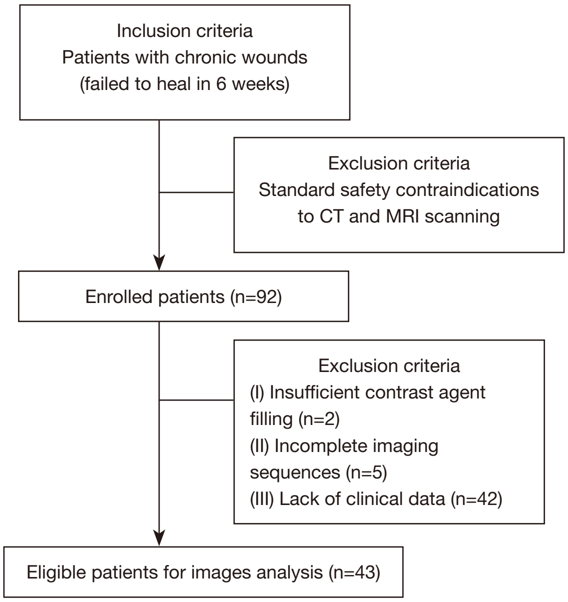

Figure 1 Flow chart illustrating the patient inclusion and exclusion criteria.

and the side effects of contrast agent.

Images analysis

For each anonymized participant, 2 imaging examinations were randomly allocated in 2 reading sessions by a referee not involved in the imaging analysis. A single examination (CT or MRI) per patient was presented in random order in each session. The images were individually reviewed by 2 trained radiologists with 7 years of experience (Z.L. and Y.P.), who were blinded to the clinical data in 2 sessions with a 4-week interval, and the following features were assessed: (I) shape of the chronic wound; (II) number of branches; (III) whether the chronic wound involved the body cavity; (IV) whether the chronic wound involved any bones. The shape of chronic wound was defined as a tract if the ratio of depth to maximum diameter was >2, or cavity if the ratio of depth to maximum diameter was ≤2 (13).

Statistical analysis

Kappa value was calculated to evaluate the interobserver agreement and the consistency between CT and MRI sinography/fistulography in assessing the shape of chronic wounds and the involvement of body cavity and bones. Intraclass correlation coefficient (ICC) was calculated to evaluate the interobserver agreement and the consistency between CT and MRI sinography/fistulography in assessing the number of branches in chronic wounds. A kappa value or ICC value of 0.00–0.20 indicated slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; 0.81 to less than 1.00, almost perfect agreement; and 1.00, perfect agreement. Statistical significance was considered when P<0.05. We used SPSS version 22.0 (IBM Corp., Armonk, NY, USA) to perform the statistical analysis.

Results

The demographic characteristics of participants are shown in *Table 2*. The chronic wounds were demonstrated as a contrast agent-filled tract or cavity with small bubbles (65.1%, 28/43), surrounding fibrous connective tissue (72.1%, 31/43), and effusion (9.3%, 4/43).

The morphology of chronic wounds assessed by the 2 readers are shown in *Table 3*. There were substantial interobserver agreements for both CT and MRI sinography/fistulography. The consistency between CT and MRI in evaluating the shape of chronic wounds (reader 1, kappa value =1.000; reader 2, kappa value =0.932) and the number of branches [reader 1, ICC =0.951 (95% CI: 0.909–0.973, P<0.001); reader 2, ICC =0.874 (95% CI: 0.768–0.932, P<0.001)] was almost perfect for the 2 readers.

The involvement of body cavity and bones in chronic wounds is shown in *Table 4*. The interobserver agreements for CT and MRI sinography/fistulography were substantial to almost perfect, which was same for the consistency between CT and MRI sinography/fistulography in evaluating the involvement of body cavity (reader 1, kappa value =0.728; reader 2, kappa value =0.775) and bones (reader 1, kappa value =0.659; reader 2, kappa value =0.860) (*Figure 2*, *Figure 3*).

Discussion

Chronic wounds often form sinus/fistulas with complex deep structures, causing difficulties in their diagnosis and treatment. In this study, we found CT and MRI sinography/fistulography had good interobserver agreements and consistency between each other in evaluating the shape, number of branches, and involvement of body cavity of chronic wounds. The results indicated that CT and MRI sinography/fistulography could be reliable imaging techniques for accurately assessing chronic wounds.

Table 1 Parameters of the MRI protocol

Parameters	TR/TE (m/s)	Field of view (mm^2)	Matrix	Slice thickness (mm)	Flip angle (deg)	No. of slices	Acquisition time (min:s)
Extremity							
Axial T1w	450.00/12.00	360	202×448	3.5	180	23	01:51
Axial fat-saturated T1w	700.00/10.00	360	168×320	3.5	150	23	02:00
Axial fat-saturated T2w	3,500.00/55.00	360	180×320	4.0	150	25	02:55
Coronal fat-saturated T1w	1,670.00/9.20	360	235×448	3.0	180	20	05:01
Thorax and abdomen							
Axial T1w	6.87/2.39	360	175×320	5.0	15.0	56	00:16
Axial fat-saturated T1w	4.85/2.41	380	195×320	3.0	10.0	64	00:19
Axial fat-saturated T2w	3,000.00/91.00	380	320×320	6.0	140	30	02:20
Coronal fat-saturated T1w	3.90/1.49	360	234×320	3.0	10.0	60	00:15
Pelvis and hip							
Axial T1w	827.00/21.00	250	230×256	5.0	129	26	02:30
Axial fat-saturated T1w	827.00/21.00	250	230×256	5.0	129	26	01:52
Axial fat-saturated T2w	5,080.00/86.00	250	272×320	6.0	180	24	02:34
Sagittal fat-saturated T1w	827.00/21.00	250	230×256	5.0	129	26	01:56

MRI, magnetic resonance imaging; TR, repetition time; TE, echo time; T1w, T1-weighted; T2w, T2-weighted.

Table 2 Participant characteristics

Characteristic	N (%) or median [range]
No. of included patients	43 (100.0)
Gender	
Female	22 (51.2)
Male	21 (48.8)
Median age (years)	65 [18–94]
Site of chronic wounds	
Thorax	5 (11.6)
Abdomen	17 (39.5)
Lumbus	2 (4.7)
Hip	13 (30.2)
Upper extremity	2 (4.7)
Lower extremity	4 (9.3)
Type of chronic wound	
Sinus	40 (93.0)
Fistula	3 (7.0)

Table 2 (*continued*)

Table 2 (*continued*)

Characteristic	N (%) or median [range]
Causes of chronic wound	
Infection	15 (34.9)
Surgery	18 (41.9)
Malignancy	1 (2.3)
Pressure	9 (20.9)

These imaging techniques also provide surgeons a more comprehensive look at the morphology and deep features of chronic wounds to make an appropriate treatment plan and efficacy evaluation.

Previous studies have reported the use of CT sinography/fistulography in assessing the structural details of chronic wounds with sinus and fistula (9-12). Sun *et al.* found that CT fistulography and 3D image construction can clearly show the distribution, internal opening, and surrounding structure of congenital branchial cleft fistula and sinus (10). Thorpe *et al.* performed preoperative CT fistulography on

Table 3 Morphology of chronic wounds

Parameter	Shape, n (%)				Number of branches, n (%)					
	CT		MRI		CT			MRI		
	Tract	Cavity	Tract	Cavity	0	2	≥3	0	2	≥3
Reader 1	37 (86.0)	6 (14.0)	37 (86.0)	6 (14.0)	31 (72.1)	10 (23.3)	2 (4.7)	33 (76.7)	8 (18.6)	2 (4.7)
Reader 2	34 (79.1)	9 (20.9)	33 (76.7)	10 (23.3)	32 (74.4)	8 (18.6)	3 (7.0)	33 (76.7)	7 (16.3)	3 (7.0)
Interobserver agreement	Kappa value =0.760		Kappa value =0.697		ICC =0.807 (95% CI: 0.643–0.895, P<0.001)			ICC =0.727 (95% CI: 0.495–0.852, P<0.001)		

CT, computed tomography; MRI, magnetic resonance imaging; ICC, intraclass correlation coefficient; CI, confidence interval.

Table 4 Involvement of body cavity and bones in chronic wounds

Parameter	Body cavity, n (%)		Bones, n (%)	
	CT	MRI	CT	MRI
Reader 1	7 (16.3)	6 (14.0)	7 (16.3)	7 (16.3)
Reader 2	6 (14.0)	4 (9.3)	10 (23.3)	8 (18.6)
Interobserver agreement (kappa value)	0.909	0.775	0.782	0.758

CT, computed tomography; MRI, magnetic resonance imaging.

a patient with branchial cleft sinus and found this technique facilitated excellent demonstration of the course and extent of the tract (11). The CT fistulography is also able to demonstrate the type of perianal fistula, its extent, whether it is simple or complex, and the site of internal opening and associated complications (9). However, CT sinography/fistulography still has limitations such as low soft tissue resolution, high radiation dose, and inability to clearly show the morphology of sinus/fistula if the contrast agent is insufficiently filled.

The benefits of MRI include its sensitivity to soft tissue and ability to precisely define the extent of infection in wounds (14). Lee *et al.* found that MRI can show the location, internal and external openings of limited dorsal myeloschisis and congenital dermal sinus, and help to differentially diagnose them (15). Soker *et al.* performed CT fistulography and MRI on perianal fistulae, and confirmed that both CT and MRI can clearly demonstrate the number of branches, with MRI showing more advantages in fistula classification, internal opening detection, and the identification of acute and chronic fistulas (12). Lane *et al.* found axial and sagittal MRI had high sensitivity and specificity in diagnosing dermal sinus of the lumbosacral spine in children (16). Besides, as 3D reconstruction of MR images help surgeons to observe chronic wounds from different angles, it has been shown to reveal the course, depth, and morphology more clearly (17). In our study, we combined MRI and sinography/fistulography to show the extent of sinus/fistula tracts and distinguish them from surrounding soft tissue more clearly. However, we also found CT has better performance for interobserver agreements than MRI, which may be due to that CT is more sensitive to contrast agent. Besides, CT has a higher ability in detecting some kinds of foreign matter such as small pieces of metal and plastic (18). Therefore, we should combine CT and MRI images in diagnosis of chronic wounds.

As for other imaging techniques used for the evaluation of chronic wounds, although conventional X-ray sinography/fistulography can show their shape and course, it is unable to clearly show the deep features and relationship with surrounding tissue, because of its low soft tissue resolution. Thus, it has a very limited role in diagnosis and treatment of chronic wounds. Ultrasound has been widely used in wound imaging because of its convenience, low cost, high resolution, and real-time response (3); however, it has limited penetration depth and does not easily reveal the deep features of chronic wounds. Besides, evaluation of narrow and tortuous sinus/fistula tract is susceptible to interference from surrounding muscle with similar echoes.

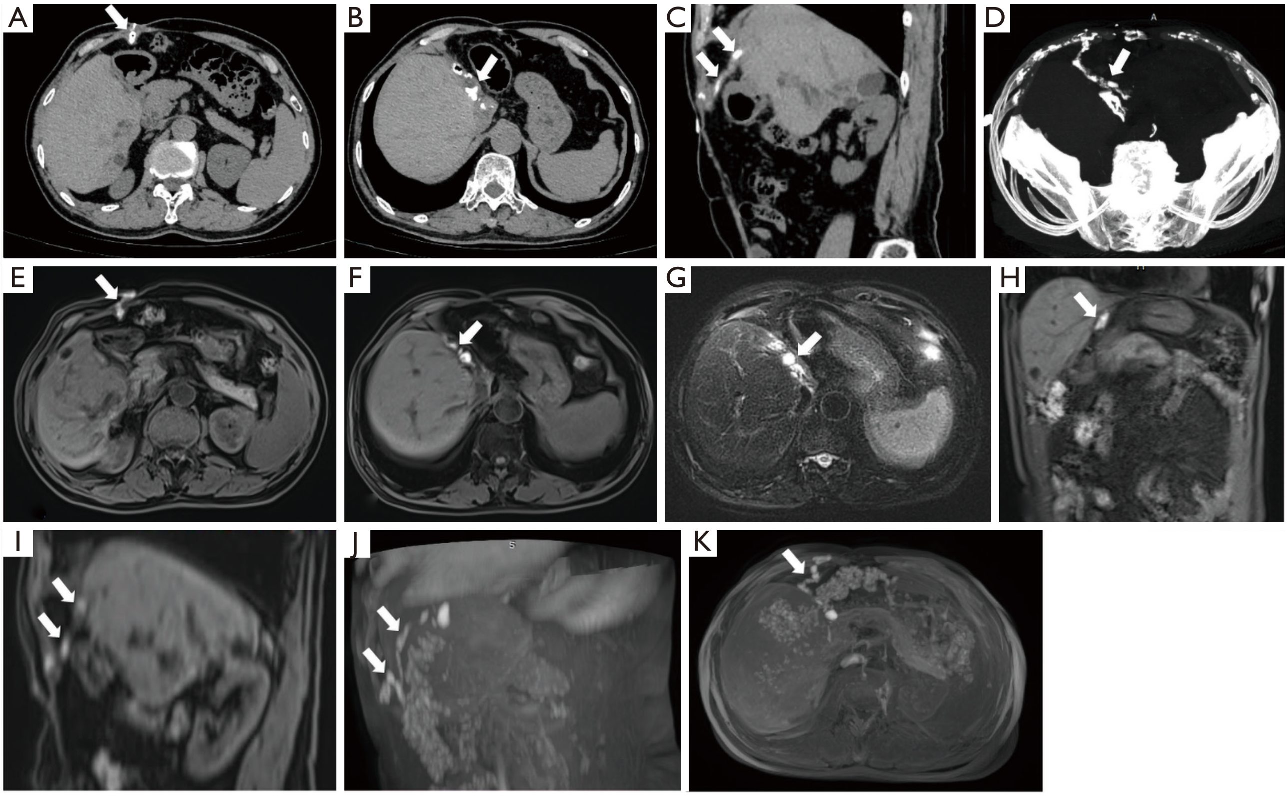

Figure 2 A 66-year-old man diagnosed with abdominal chronic wounds 2 years after partial hepatectomy. (A-D) CT images of sinography/fistulography, MPR and MIP; (E-H) MR sinography/fistulography images of axial fat-saturated T1w, axial fat-saturated T2w and coronal fat-saturated T1w sequences; (I-K) MR images of MPR and MIP. The chronic wounds (white arrows) demonstrated as a contrast agent filled tortuous sinus tract with small bubbles, involving abdominal cavity and extending to liver. CT, computed tomography; MR, magnetic resonance; MIP, maximum intensity projection; MPR, multiplanar reconstruction.

Thus, ultrasound may miss branches in some cases and is unable to accurately assess the morphology and course of chronic wounds. Contrast-enhanced ultrasound may be able to lift its application restrictions, as it can show the morphology of chronic wounds better. But it has limited value for wounds with bone destruction, lung and digestive tract involvement.

There were some limitations to this study. First, it was a single-center prospective study with a limited sample size. Therefore, further validation of CT and MRI sinography/fistulography is needed via larger cohort studies. Second, although we had taken measures to fill the wound as full as possible by contrast agent (i.e., the surgeons cleaned away foreign matter and pus before CT and MR scanning), the contrast agent may have still been insufficiently filled in some cases, especially those with narrow tract and multiple branches, which is thought to be one of the limitations of sinography/fistulography. Last, there was a lack of "gold standard" of chronic wound evaluation in the study. Endoscopy and conventional probe exploration often fail to reach the bottom of the wound or detect all the branches. Surgery helps to detect the deep features of chronic wounds; however, a few of the patients with chronic wounds received surgery, which may have destroyed the morphology of chronic wounds. It is therefore difficult to determine whether CT and MR images reflect the real morphology and deep features of chronic wounds. A combination of CT and MRI sinography/fistulography with endoscopy exploration may have the potential to become the gold standard of chronic wound evaluation. We need further study to evaluate its diagnostic value and compare it with other technologies such as ultrasound.

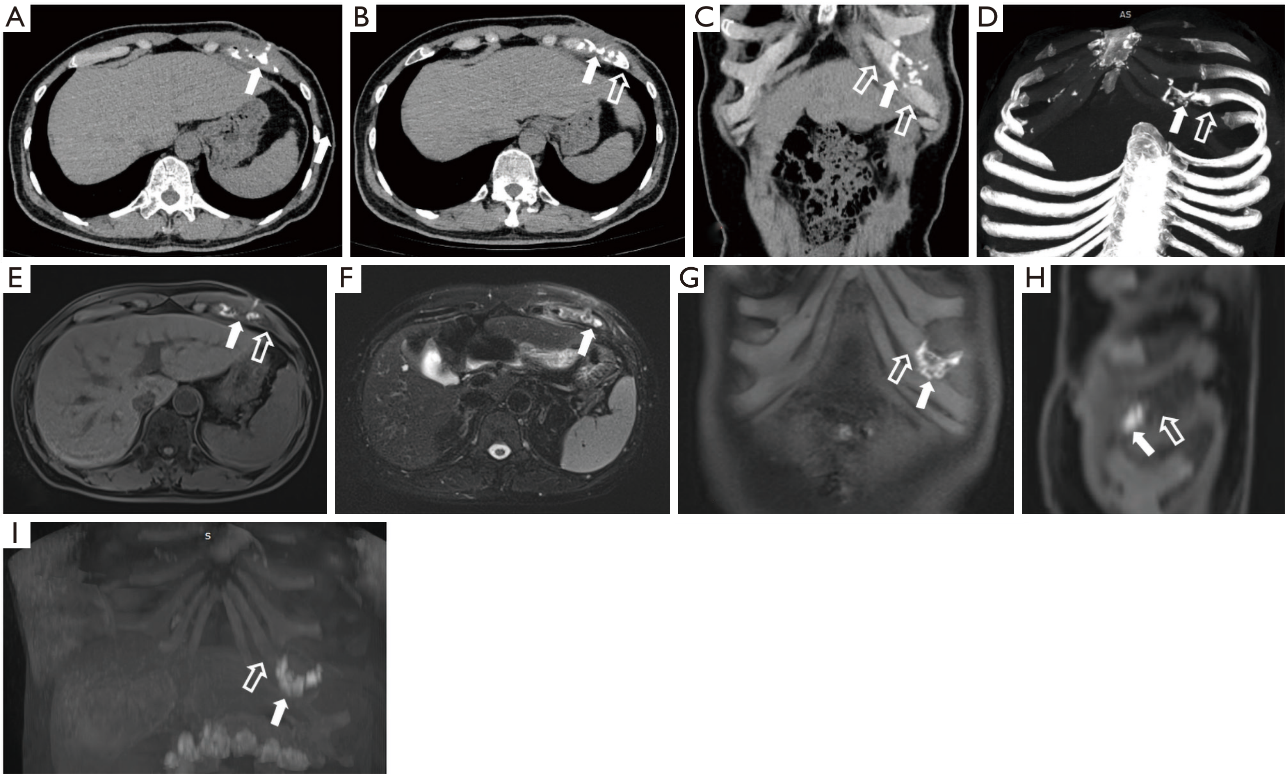

Figure 3 A 56-year-old man diagnosed with abdominal chronic wounds 10 months after abscess incision and drainage. (A-D) CT images of sinography/fistulography, MPR and MIP; (E-G) MR sinography/fistulography images of axial fat-saturated T1w, coronal fat-saturated T1w and axial fat-saturated T2w sequences; (H,I) MR images of MPR and MIP. The chronic wounds (white arrows) demonstrated as a contrast agent filled sinus cavity with small bubbles and surrounding soft tissue edema, involving left rib and costal cartilage (open arrows). CT, computed tomography; MR, magnetic resonance; MIP, maximum intensity projection; MPR, multiplanar reconstruction.

Conclusions

In conclusion, CT and MRI sinography/fistulography had good interobserver agreements and consistency between each other in evaluating the morphology and deep features of chronic wounds. Therefore, CT and MRI sinography/fistulography could be reliable imaging techniques for chronic wounds and facilitate the evaluation of diagnosis, treatment, and healing.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://dx.doi.org/10.21037/apm-21-2342

Data Sharing Statement: Available at https://dx.doi.org/10.21037/apm-21-2342

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). This prospective study was approved by the institutional review board of Ruijin Hospital, Shanghai Jiao Tong University School of Medicine (No. 2018-27), and written informed consent was provided by each patient.

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