Surg Endosc (2013) 27:3911–3920
DOI 10.1007/s00464-013-2948-x

DYNAMIC MANUSCRIPTS

Transluminal retroperitoneal endoscopic necrosectomy with the use of hydrogen peroxide and without external irrigation: a novel approach for the treatment of walled-off pancreatic necrosis

Mohamed Abdelhafez · Mayada Elnegouly · M. S. Hasab Allah · Mostafa Elshazli · Hany M. S. Mikhail · Ayman Yosry

Received: 12 October 2012 / Accepted: 20 March 2013 / Published online: 13 April 2013

Abstract
Background Transluminal retroperitoneal endoscopic necrosectomy (TREN) is an attractive NOTES technique alternative to surgery for treatment of walled-off pancreatic necrosis (WOPN). The main limitations to this technique are the need for repeated sessions, prolonged external irrigation, and EUS availability. In our study, we introduced new modifications, including the use of hydrogen peroxide, and abandoning the use of EUS and external irrigation.
Methods This is a retrospective study of outcome of consecutive patients who underwent TREN for WOPN between April 2011 and August 2012. The technique included (1) non-EUS–guided transluminal drainage, and (2) direct endoscopic debridement using hydrogen peroxide and different accessories. No external irrigation was used.
Results Ten patients were included. Initial clinical and technical success was achieved in all patients. Complete radiological success and long-term clinical efficacy was achieved in nine patients (1 patient had an inaccessible left paracolic gutter collection and died 62 days after endotherapy). Mean number of sessions was 1.4 (range 1–2). Complications included bleeding, which was self-limited in three patients and endoscopically controlled in one. All patients avoided surgery, and no recurrence was reported during median follow-up of 289 (range 133–429) days.
Conclusions TREN is a safe and effective treatment for WOPN and could be performed safely without EUS guidance in selected cases. Hydrogen peroxide played a major role in reduction of number of sessions and timing. External irrigation of WOPN is not necessary, if adequate debridement could be achieved.

Keywords Endoscopic necrosectomy · Walled-off pancreatic necrosis · NOTES · Debridement · Hydrogen peroxide · Acute pancreatitis

Pancreatic necrosis is one of the most severe complications of acute pancreatitis and is defined, according to Atlanta classification, as diffuse or focal areas of nonviable pancreatic parenchyma, which is typically associated with peripancreatic fat necrosis [1]. During a period of 3–4 weeks, sequestration of necrotic tissue occurs, forming a relatively well-circumscribed fibrous capsule without an epithelial lining, recently referred to as walled-off pancreatic necrosis (WOPN) [2, 3]. Infection of WOPN develops in as many as 70 % of cases with mortality rate reaching up to 100 % if appropriate intervention was not undertaken [4].

Surgical necrosectomy has remained the mainstay of treatment for WOPN. However, mortality rate with open surgery can be as high as 56 % with a mean of 25 %, and repeated laparotomies are usually needed [5–10].

Recently, minimally invasive techniques have been developed as an alternative to open surgery in selected

Electronic supplementary material The online version of this article (doi:10.1007/s00464-013-2948-x) contains supplementary material, which is available to authorized users.

M. Abdelhafez (✉) · M. Elnegouly · A. Yosry
Gastrointestinal Endoscopy Unit, Faculty of Medicine, Kasr Alainy Hospital, Cairo University, Cairo, Egypt
e-mail: dr_mhafez@hotmail.com

M. S. Hasab Allah
Endemic Medicine Department and Hepatogastroenterology, Faculty of Medicine, Kasr Alainy Hospital, Cairo University, Cairo, Egypt

M. Elshazli · H. M. S. Mikhail
General Surgery Department, Faculty of Medicine, Kasr Alainy Hospital, Cairo University, Cairo, Egypt

patients, with significant better outcomes. These techniques have included image-guided, large-bore catheter drainage [11–13], laparoscopic necrosectomy [14–16], and minimally invasive visually assisted retroperitoneal debridement [17, 18]. The common concept beyond these techniques is to have a direct access to the WOPN for drainage and debridement through a minimal yet limited access approach.

Endoscopic transluminal access to the abdominal cavity without creating scars, which is called "natural orifice transluminal endoscopic surgery" (NOTES), is an emerging technique attracting great interest and being evaluated experimentally for variety of procedures [19, 20]. Peroral transluminal retroperitoneal endoscopic necrosectomy (TREN) for WOPN is the first clinical application of NOTES and was pioneered in 2000 by Seifert [21]. This technique offers another minimally invasive approach and allows more aggressive debridement in selected patients, with high success rate and low mortality and morbidity rates [3, 22–24].

This is the first study conducted to assess the safety and efficacy of TREN technique in Kasr Alainy Hospital, Cairo University, the largest tertiary hospital in Egypt, with initial outcome and long-term follow-up. Contrary to previous publications, neither endoscopic ultrasound (EUS) nor external irrigation were used in this study. To our knowledge, this the first time in literature that safety and efficacy of hydrogen peroxide use to facilitate the debridement process was assessed.

Patients and methods

We have established our multidisciplinary team since 2010 to manage cases with different types of pancreatic fluid collections (PFC). Our team consists of an experienced endoscopist, gastrointestinal surgeons, and an expert interventional radiologist. After initial success and favorable outcome with our first case of TREN in April 2011, all cases with WOPN who fulfilled our selection criteria were enrolled for endoscopic necrosectomy. All patients were informed that this technique is still under development. Alternative options were presented, various expected complications were discussed, and written consent was obtained. At our institution and others in Egypt, retrospective analysis of clinical information does not require a specific approval by an institutional review board.

Data of ten consecutive patients (6 males, 4 females) who underwent TREN for WOPN during the period from April 2011 to August 2012 were prospectively collected and retrospectively analyzed.

Clinical data, etiologies, and duration of pancreatitis were recorded. Full laboratory assessment was done, and Acute Physiology and Chronic Health Evaluation II (APACHE II) score was calculated 24 h before TREN. Abdominal ultrasound, contrast-enhanced CT (CECT) scan, and MRCP were performed to assess the number, size, location, wall thickness, relation to the upper gastrointestinal lumen, and presence of solid debris inside the PFC. Also portal and splenic veins, biliary system, pancreatic parenchyma, and main pancreatic duct were assessed (Figs. 1, 2).

All selected patients for endoscopic debridement had symptomatic collections and/or highly suspected infection. Main indicating symptoms were abdominal pain necessitating pain killers, cholestasis, and inability to eat or weight loss. Infection was suspected with fever, leukocytosis, presence of air inside the WOPN in CECT, and/or positive culture from WOPN aspirate or blood culture.

All patients were examined with ultrasound and CECT scan. Four patients had MRCP. Presence of wall adherent to the gastric or duodenal wall and less than 10 mm in thickness was essential. PFCs were confirmed to be WOPN by visualizing solid debris inside, using abdominal ultrasound or CECT scan.

All patients had diagnostic upper endoscopy before the procedure. Presence of a visible bulge caused by the WOPN on the gastric or duodenal lumen was mandatory, as EUS was not available for nonbulging lesions. Patients who were found to have PFCs with minimal or no necrosis upon the entrance of the scope into the cyst cavity were excluded from this study.

Endotherapy

All patients underwent the endotherapy under deep sedation with propofol in the prone position. Anesthesiologist was available during all procedures. All patients were maintained on broad-spectrum antibiotics before and after the endotherapy.

All procedures started with examining the upper GI tract to determine the appropriate site for the transluminal puncture. The site was chosen as the most prominent area in the bulge caused by the external compression on the posterior gastric or medial duodenal wall, while referencing the most recent CECT. Therapeutic side-viewing duodenoscope (Olympus TJF-Q180V or Pentax ED3410) was used for stoma creation (see imbedded video clips).

An electrocautery three-way needle knife was used for puncture. Successful penetration was considered with aspiration of WOPN fluid content and was confirmed by coiling a standard 0.035 guidewire and injection of a contrast medium inside the WOPN cavity. Aspirates from the WOPN were sent for bacteriologic culture.

The needle knife was exchanged with a balloon dilator over the guidewire. Gradual dilation of the puncture track

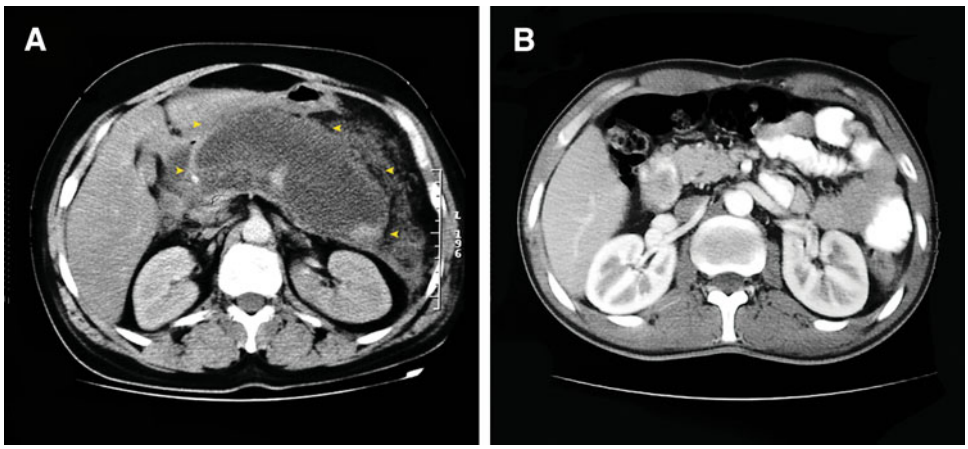

Fig. 1 **A** Abdominal CECT showing extensive central WOPN. **B** Abdominal CECT for the same patient showing complete resolution of the WOPN after TREN

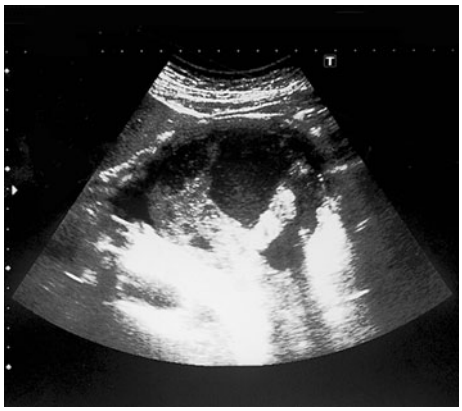

Fig. 2 Abdominal ultrasound imaging confirming the diagnosis of WOPN by presence of large amount of solid debris inside the PFC

was achieved under fluoroscopic guidance by starting with 8-mm balloon dilator followed by further dilatation to the maximum diameter of 16–20 mm. Gushing of the fluid content of the WOPN was noted in all cases and was described as purulent, dark brown, or turbid material (Figs. 3, 4).

The side-viewing scope was then exchanged with front viewing scope (Olympus GIF-H260 or Pentax EG-2930) for the debridement process. Upon entrance inside the WOPN cavity, the amount of necrosis was assessed. Vigorous irrigation with saline followed by continuous suction was done. Total amount of 100–300 cc of 0.1–0.3 % hydrogen peroxide was sprayed directly over the necrotic material, followed by irrigation with normal saline and suction. Different types of accessories, including polypectomy snare, stone retrieval basket, twister, and rat-toothed forceps, were used after irrigation to detach the necrotic material. Most of the retrieved necrotic material was removed to the gastric or duodenal cavity, whereas some pieces were brought for cytology examination. The purpose of the debridement was to remove all the necrotic tissue until healthy pink granulation tissue that oozes blood becomes exposed. The process was terminated when full debridement was achieved or when the anesthesiologist demanded it. At the end of the procedure, irrigation with saline and Garamycin was done, and double pigtail stents were inserted. Repeated sessions of debridement were performed when needed (Figs. 5, 6).

ERCP was performed when pancreatic ductal anomaly and/or biliary obstruction were suspected upon imaging studies.

Outcome and follow-up parameters

Abdominal ultrasound and CECT scan were undertaken within 1 week of every session. All procedure-related complications, clinical symptoms and signs, and duration of the hospital stay were recorded.

Initial success was considered, at hospital discharge or within the first 30 days of the first session, when all of the following was achieved:

- Clinical success was considered when all of the indicating symptoms had disappeared. Persistence of symptoms or fever was considered as failure.
- Imaging success was defined as complete resolution of the WOPN. Presence of unchanged or large amount of fluid collection (>3 cm) was considered as failure. In patients who had more than one WOPN, failure to resolve one of the lesions due to its inaccessibility was considered as separate entity.
- Complications that needed alternative interventions were considered as failure.

Long-term follow-up was started upon hospital discharge or after 30 days of first session, by direct interviews and phone calls. Quality of life (QoL) index was calculated, with a score from 0 (best) to 10 (worst), using Spitzer-QLI questionnaire. Follow-up imaging was done regularly, mainly with abdominal ultrasound. Late complications,

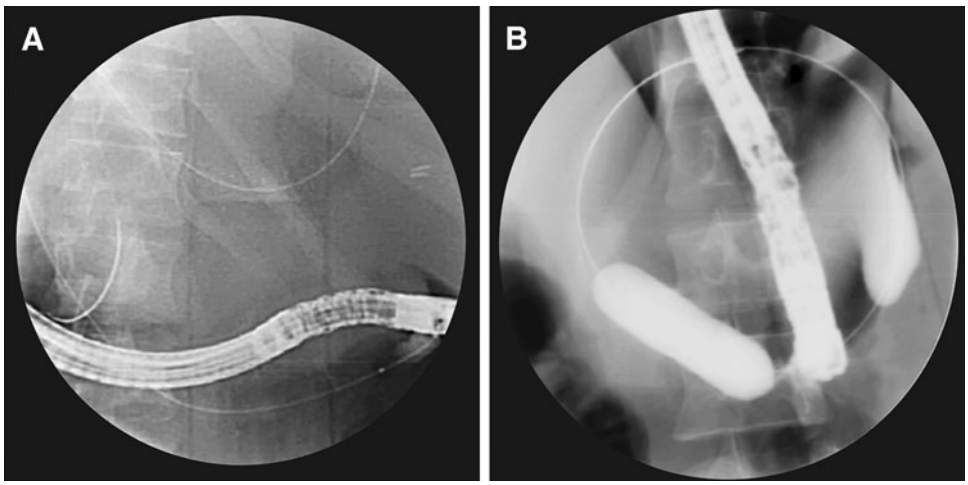

Fig. 3 Fluoroscopic images showing coiling of the guidewire inside the WOPN cavity after the puncture (**A**) and balloon dilatation of the stoma (**B**)

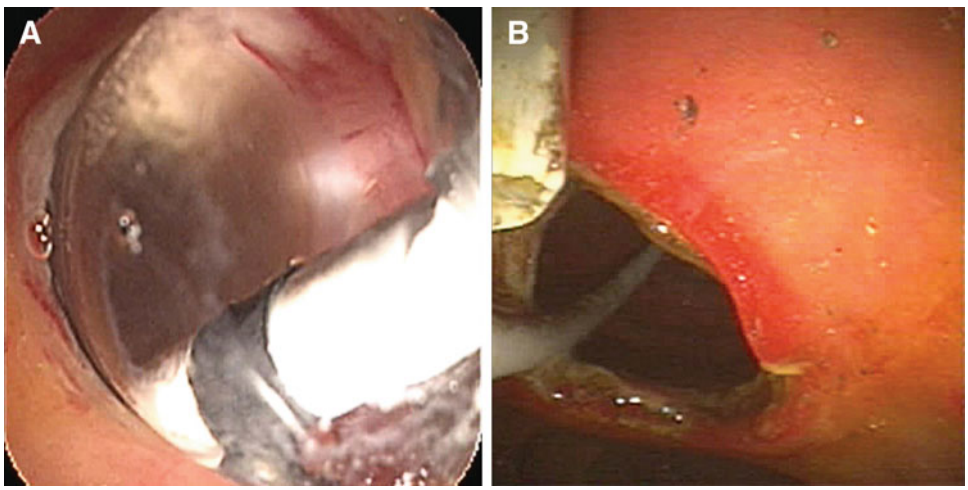

Fig. 4 Endoscopic images showing balloon dilatation of the enterostoma up to 20 mm (**A**) and the appearance of the stoma with a pigtail during the TREN technique (**B**)

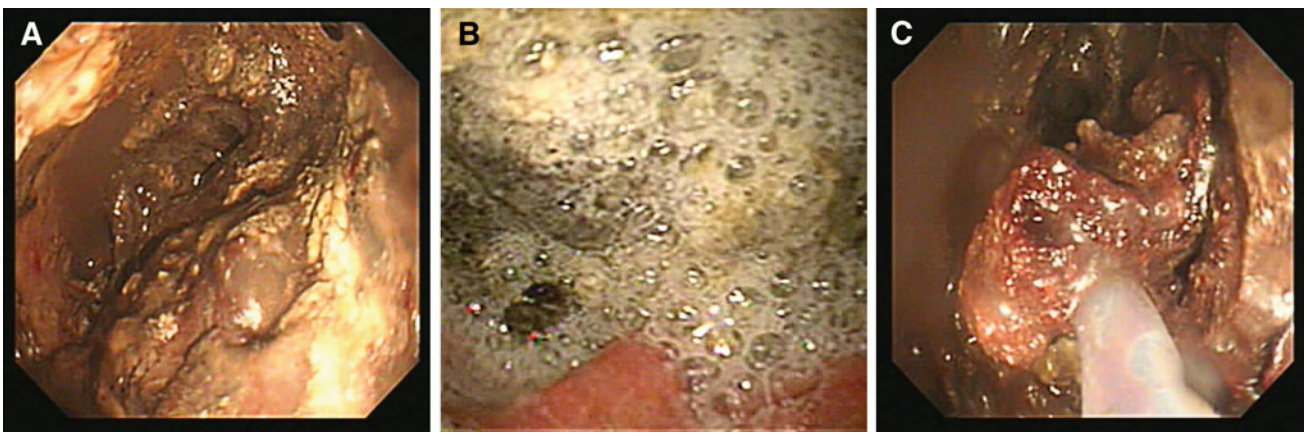

Fig. 5 Endoscopic images showing WOPN cavity with large amount of necrotic material (**A**), the effervescence effect of hydrogen peroxide after spraying on the necrotic material (**B**), and extraction of large piece of necrotic material with polypectomy snare (**C**)

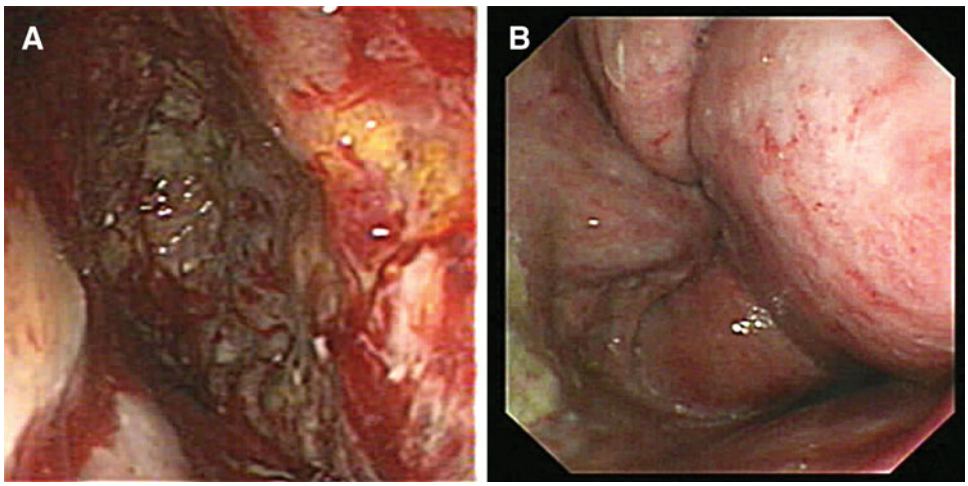

Fig. 6 Endoscopic imaging showing exposure of the healthy, pink, easily bleeding granulation tissue after full debridement at the end of the TREN (**A**) and the same cavity 2 weeks later showing complete absence of necrotic debris (**B**)

recurrence, need for rehospitalization, need for other interventions, and mortalities were recorded.

Results

Patient data

Ten patients (6 males and 4 females) were included with a mean age of 44 (range 29–78) years. Patients and WOPN characteristics are detailed in Tables 1 and 2.

Median APACHE II score was 7 (range 0–22). Only one patient was a nonoperative candidate due to age extremity and multiple comorbidities. Infected WOPN was confirmed in seven patients. Presenting symptoms were severe abdominal pain in nine patients, cholestasis in three, and inability to eat or weight loss in eight. Three patients had previous endoscopic drainage, two had percutaneous drainage, and one had surgical necrosectomy before endotherapy.

Average size of the WOPN was 12 (range 8–18) cm. Eight patients had single cavities, whereas two patients had two separate cavities. Diagnosis of PFCs to be WOPN was confirmed by abdominal ultrasound and CECT. Ascites and pleural effusion were found in four patients. MRCP diagnosed pancreatic ductal disruption in two patients, pancreatico-peritoneal fistula in one, and disconnected duct in two.

Table 1 Clinical presentation and laboratory abnormalities

Patients ($n = 10$)	
Clinical presentation	
Sepsis	7
Abdominal pain	9
Inability to eat or weight loss	8
Cholestasis	3
Ascites and/or pleural effusion	4
Laboratory abnormalities	
Leukocytosis	7
Hypoalbuminemia	4
Renal impairment	3
BMI, median (range)	20 (13–29)
APACHE II, median (range)	7 (0–22)

BMI body mass index, *APACHE II* acute physiology and chronic health evaluation II

Endoscopic procedure

The time from the onset of acute necrotizing pancreatitis until endotherapy was mean of 65 (range 32–186) days. Access to WOPN cavity was made by puncture into the visible bulge in nine patients or through spontaneous rupture of the cyst into gastrointestinal lumen in one. Six patients had successful puncture from the first trial, whereas three patients had three to five trials before successful penetration. Five patients had transgastric access, four had transduodenal access, and one had both.

Aspirated fluid from WOPN was described as purulent in five patients, brownish in three, and turbid in two. Bacteriologic culture revealed *E. coli* in three patients, Klebsiella in three, and Enterococcus in one. Mean number of necrosectomy sessions was 1.4 per patient. Six and four patients had one and two sessions, respectively. Average time of sessions was 110 (range 75–160) minutes. Average interval time between sessions was 8 (range 4–14) days. Two 10-French double pigtails were used at the end of each session for drainage.

ERCP was performed in seven patients. Six patients had their ERCP during the first session and one during the second session. Pancreatic sphincterotomy and stenting were performed in five patients. Minor papilla sphincterotomy, stone

Table 2 Patient characteristics and outcomes

Case/ gender/ age (year)	Etiology	Admission to treatment interval (weeks)	WOPN size (location)	Prior interventions	Rout for EN (no. of sessions)	Post-procedure LOS (days)	Complications/ management	Resolution [follow-up (months)]
1/F/35	Biliary	8	12 × 10 cm, 8 × 6 cm (entire pancreas)	US drainage, endoscopic CG	TG + TD (2)	18	Remarkable bleeding/ endoscopic	Complete (14)
2/F/45	Idiopathic	9	16 × 12 cm (head)	–	TG (1)	7	–	Complete (14)
3/M/38	Iatrogenic	8	18 × 12 cm (head)	–	TD (2)	6	Aspiration/ intubation	Complete (13)
4/F/78	Biliary	7	12 × 10 cm, 3 × 4 cm (head and body, extension into the left paracolic gutter)	–	TD spontaneous rupture (1)	10	–	Complete resolution of peripancreatic WOPN. Residual paracolic gutter extension (2)
5/M/37	Biliary	8	15 × 12 cm (head and body)	–	TD (1)	7	Minor bleeding/–	Complete (10)
6/M/38	Biliary	5	12 × 10 cm (body and tail)	US drainage, endoscopic CG	TG (2)	28	Minor bleeding/–	Complete (9)
7/M/30	Idiopathic	7	10 × 8 cm (head)	Endoscopic CD	TD (1)	3	–	Complete (9)
8/M/65	Alcohol	8	12 × 9 cm (head and body)	–	TG (1)	5	–	Complete (8)
9/F/40	Idiopathic	7	15 × 11 cm (body and tail)	–	TG (2)	12	Minor bleeding/-	Complete (6)
10/M/ 37	Alcohol	26	16 × 12 cm (head and body)	Surgical CG	TG (1)	20	Stent migration/ endoscopic	Complete (4)

F female, *M* male, WOPN walled off pancreatic necrosis, *LOS* length of hospital stay, *EN* endoscopic necrosectomy, *US* ultrasound, *CG* cystogastrostomy, *CD* cystoduodenostomy, *TG* transgastric, *TD* transduodenal

extraction, and stenting was performed in one patient. CBD stent was inserted in two patients. All of the endoscopic procedures were performed by a single experienced interventional endoscopist (MA).

Procedure-related complications

One patient had a remarkable bleeding during needle knife penetration, which was controlled endoscopically with diathermy and epinephrine injection. The procedure was continued, and no blood transfusion was needed. Also during penetration, three patients had minor bleeding that stopped spontaneously without intervention.

Aspiration occurred in one patient during the procedure, which needed intubation and suction. The procedure was postponed to a later date. Patient chest examination and x-ray showed insignificant findings.

In one patient, two single pigtail stents migrated inwards and the gastrostoma closed spontaneously within 10 days. Cavity repenetration, redilatation, and stents retrieval were successful without further complications.

Initial outcome

The average time of hospital stay after the first TREN session was 11 (range 3–28) days. Clinical success was achieved in all patients following endoscopic necrosectomy. All presenting symptoms significantly improved and fever subsided in all patients within 48 h of initial endotherapy. All patients could tolerate oral feeding within 48 h of procedure.

Complete radiological success was achieved in nine patients, with complete resolution of the WOPN in CECT and ultrasound imaging. In one patient who had two non-contagious WOPN cavities, one cavity (12 × 10 cm) was

completely resolved after TREN, whereas the other one (3 × 4 cm) could not be accessed endoscopically due to its location in the left paracolic gutter. Also, ultrasound-guided drainage could not be done for this WOPN cavity due to its proximity to the pleura. However, after resolution of the large WOPN the patient was symptom-free and was discharged at day 15. In four patients, ascites and pleural effusion had completely resolved after TREN and transpapillary pancreatic stenting.

Long-term follow-up

There was one death among our study. This patient (78 years old) had residual inaccessible WOPN cavity mentioned above. The patient was rehospitalized with fever, 42 days after hospital discharge, and died at day 65 with septic shock.

Mean time of follow-up for the nine survival patients was 289 (range 133–429) days. All patients returned to their baseline weights or continue to gain weight appropriately. All patients tolerate unrestricted diet without pancreatic enzyme supplementations. No recurrence of PFCs was found in follow up ultrasound or CECT scan in all patients. The median QoL index was 1.2 (range 0–5). Two patients are taking oral analgesics occasionally for chronic abdominal pain. Both of these patients have disconnected duct syndrome and were advised for surgery, but refused.

Discussion

With the beginning of the new millennium, endotherapy has played a major role in the management of PFCs. Distinction between different types of PFCs is extremely important in choosing the best management strategy. PFCs types include acute peripancreatic fluid collections, pancreatic pseudocysts, pancreatic abscesses, and WOPN. More than 50 % of cases of acute peripancreatic fluid collections will resolve spontaneously, whereas the rest will develop into other types of PFCs [25, 26]. Standard transluminal endoscopic drainage for pancreatic pseudocysts and pancreatic abscesses has gained a wide acceptance and is considered as the treatment of choice by many authors, with success rate varied from 82 to 97 % [27–29]. In case of WOPN, standard endoscopic drainage does not suffice to achieve resolution, because necrotic debris will prevent adequate drainage and will promote secondary infection [28–31]. This obstacle raised the need to introduce an endoscope inside the WOPN cavity after proper dilatation to achieve debridement of the necrotic debris. This technique was innovated by Seifert in 2000 and followed by multiple studies to evaluate and modify the technique in different centers worldwide [21, 24].

Conventional therapy for WOPN remains open surgery that involves large incisions and extensive dissections with mean mortality rate of 25 % [5–10]. Our study showed that TREN could be an attractive and less invasive treatment for WOPN with high clinical success rate and very low rate of complications. Nine of our patients were operative candidates and infected WOPN was confirmed in seven. We have achieved initial clinical success in all ten patients and long-term clinical efficacy in nine. One inoperable candidate patient died during the long-term follow-up due to septic shock, 62 days after hospital discharge. This patient had another collection in the left paracolic gutter, which was inaccessible endoscopically or radiologically. Our results are consistent with previously published studies that showed success rate ranging from 84 to 100 % and complication rate ranging from 0 to 26 % [22–24, 32, 33]. Surgery was avoided in all of our patients.

Another advantage of the endotherapy is the ability to perform ERCP during TREN sessions, to diagnose and treat cholestasis, pancreatic duct fistulas, disruptions, strictures and stones, and thus prevent further recurrence of acute pancreatitis and WOPN.

Although previous publications had shown that multiple endoscopic sessions were needed to achieve adequate debridement, our study suggests that the number and timing of sessions could be significantly reduced. In one large study of 93 patients by Seifert et al. [24], the median number of sessions was 6.2 (range 1–35). In another study of 13 patients, Seewald et al. [22] reported that median number of sessions was seven (range 2–23). Georgios et al. [3] reported a median number of sessions in 53 patients to be three (range 1–12). In our study, the median number of sessions was 1.4 (range 1–2) with average time of sessions of 110 (range 75–160) min. We believe that this reduction in session numbers and time was due to the use of hydrogen peroxide to facilitate the debridement process.

Hydrogen peroxide is a clear and odorless liquid that rapidly decomposes into water and oxygen when it combines with organic tissue, producing effervescence that mechanically cleans wounds and removes tissue debris via the released oxygen [34, 35]. There are several reports on the adverse effects of the use of hydrogen peroxide. However, these adverse effects were mainly seen with high concentrations 10–35 %, 100–350-fold of our used concentration and included mucosal ulcerations and air embolism [36–39]. Kalloo et al. [40] reported the safety of endoscopic use of 3 % hydrogen peroxide in acute upper gastrointestinal bleeding to enhance visualization and to achieve hemostasis. Although there is no available data in the literature about the use of hydrogen peroxide in the management of WOPN, Aoun reported its safety and efficacy in a single case in 2010 [41].

In our study, we were spraying 0.1–0.2 % hydrogen peroxide under direct vision over the tightly adherent necrotic debris, followed by vigorous irrigation with normal saline and suction. The hydrogen peroxide significantly helped to loosen the necrotic material, which was then removed easily with accessories or suction. This technique exempted us from tedious and frustrating forceful traction of the tightly adherent necrotic material and thus decreased the procedure time and the debridement complications. No adverse effects related to the use of hydrogen peroxide were documented in our study.

Unavailability of the EUS in our study made the presence of bulging sign in the gastric or duodenal lumen mandatory. Almost all of the published studies about TREN had utilized the EUS with most of their cases to identify the most proper and safest site for puncture [22–24, 30, 33, 42, 43]. However, Gardner et al. [30] in his study of 25 patients who underwent TREN reported that, "The use of EUS did not prevent bleeding complications, either at the time of initial cavity puncture or during subsequent necrosectomy". Multiple reports prove that blind transluminal drainage can be safely performed under specific criteria [27–29, 44]. Also, in one nonrandomized comparative trial including 99 patients, there were no significant differences regarding safety or efficacy between the blind transluminal drainage group and the EUS-guided drainage group [44]. In our study, only one patient had encountered bleeding in the form of spirting vessel during the puncture attempt but that was controlled endoscopically. Our data suggest that TREN can be performed safely without EUS guidance in the presence of visible lumen bulge. EUS can be preserved for cases without bulging sign, failure of blind transluminal drainage, coagulopathy, and/or presence of intervening varices [45].

Most of the published studies had reported the use of external irrigation of the WOPN cavity in between TREN sessions, through nasocystic or percutaneous endoscopic gastrostomy tubes [22–24, 30, 33, 42, 43]. Jürgensen et al. [46] raised a question in the literature about the necessity of the irrigation, in a study enrolling 35 patients, in which neither endoscopic nor external irrigation was used. They had reported, "Even without irrigation, the outcome for patients treated with endoscopic necrosectomy is comparable to that described in the published data." In our study, although the endoscopic irrigation was used, no external irrigation was done in any patient because most of the debridement process was undertaken during the first session. This did not interfere with the number or timing of TREN sessions, or the outcome. Again, we believe that the use of hydrogen peroxide allowed us to abandon the use of external drainage, due to its capability to accelerate and facilitate the debridement and shedding off the necrotic debris. Five of our patients reported vomiting of large pieces of necrotic material or passing them with the stool during the first few days of the TREN session. Our results confirm that if adequate stoma dilatation and debridement could be achieved, external irrigation is not necessary and it could be a burden.

Procedure-related complications in this study were low and comparable to other published data. There were no procedure-related mortalities or need for surgical intervention. One remarkable bleeding occurred and was controlled easily. Minor bleeding that stops spontaneously occurred in three cases and appears to be universal during the puncture process. Stent migration inside the cyst occurred in one patient when single pigtail stents were used and were retrieved successfully. We did not encounter any perforation during this study. All of the drainage pigtails that were inserted during the last session of TREN in this study were left in place until the time of publishing of this article, without any reported complications.

Conclusions

TREN is a safe and effective primary treatment for WOPN and could be performed safely without EUS guidance in selected cases. Hydrogen peroxide use with TREN played a major role in reduction of the number of sessions and timing. External irrigation of the WOPN is not necessary if adequate debridement could be achieved. All types of PFCs should be managed in highly specialized centers with multidisciplinary teams consisting of endoscopists, surgeons, and interventional radiologists. Randomized comparative studies should be conducted to compare TREN with other newly developed minimally invasive treatment modalities. In addition, the safety and efficacy of hydrogen peroxide and/or other chemical debridement agents needs to be evaluated in larger trials, as they appear to have promising outcomes.

Acknowledgments Special thanks to the team nurse Nema Mahdy for her excellent and dedicated work.

Disclosures Drs. Mohamed Abdelhafez, Mayada Elnegouly, M. S. Hasab Allah, Mostafa Elshazli, Hany M. S. Mikhail, and Ayman Yosry have no conflict of interest or financial ties to disclose.

References

1. Bradely El III (1993) A clinically based classification system for acute pancreatitis. Summary of the International Symposium on Acute pancreatitis, Atlanta, GA, September 11 through 13, 1992. Arch Surg 128:586–590
2. Stamatakos M, Stefanaki C, Kontzoglou K, Stergiopoulos S, Giannopoulos G, Safioleas M (2010) Walled-off pancreatic necrosis. World J Gastroenterol 16(14):1707–1712
3. Papachristou GI, Takahashi N, Chahal P, Sarr MG, Baron TH (2007) Peroral endoscopic drainage/debridement of walled-off pancreatic necrosis. Ann Surg 245(6):943–951

4. Baron TH, Morgan DE (1999) Acute necrotizing pancreatitis. N Engl J Med 340(18):1412–1417
5. Fernández-del Castillo C, Rattner DW, Makary MA, Mostafavi A, McGrath D, Warshaw AL (1998) Debridement and closed packing for the treatment of necrotizing pancreatitis. Ann Surg 228(5):676–684
6. Mier J, León EL, Castillo A, Robledo F, Blanco R (1997) Early versus late necrosectomy in severe necrotizing pancreatitis. Am J Surg 173(2):71–75
7. Besselink MG, Verwer TJ, Schoenmaeckers EJ, Buskens E, Ridwan BU, Visser MR, Nieuwenhuijs VB, Gooszen HG (2007) Timing of surgical intervention in necrotizing pancreatitis. Arch Surg 142(12):1194–1201
8. Tsiotos GG, Luque-de León E, Söreide JA, Bannon MP, Zietlow SP, Baerga-Varela Y, Sarr MG (1998) Management of necrotizing pancreatitis by repeated operative necrosectomy using a zipper technique. Am J Surg 175(2):91–98
9. Branum G, Galloway J, Hirchowitz W, Fendley M, Hunter J (1998) Pancreatic necrosis: results of necrosectomy, packing, and ultimate closure over drains. Ann Surg 227(6):870–877
10. Hartwig W, Werner J, Müller CA, Uhl W, Büchler MW (2002) Surgical management of severe pancreatitis including sterile necrosis. J Hepatobiliary Pancreat Surg 9(4):429–435
11. Zorger N, Hamer OW, Feuerbach S, Borisch I (2005) Percutaneous treatment of a patient with infected necrotizing pancreatitis. Nat Clin Pract Gastroenterol Hepatol 21(1):54–57
12. Cheung MT, Ho CN, Siu KW, Kwok PC (2005) Percutaneous drainage and necrosectomy in the management of pancreatic necrosis. ANZ J Surg 75(4):204–207
13. Endlicher E, Völk M, Feuerbach S, Schölmerich J, Schäffler A, Messmann H (2003) Long-term follow-up of patients with necrotizing pancreatitis treated by percutaneous necrosectomy. Hepatogastroenterology 50(54):2225–2228
14. Zhu JF, Fan XH, Zhang XH (2001) Laparoscopic treatment of severe acute pancreatitis. Surg Endosc 15(2):146–148
15. Parekh D (2006) Laparoscopic-assisted pancreatic necrosectomy: a new surgical option for treatment of severe necrotizing pancreatitis. Arch Surg 141(9):895–903
16. Alverdy J, Vargish T, Desai T, Frawley B, Rosen B (2000) Laparoscopic intracavitary debridement of peripancreatic necrosis: preliminary report and description of the technique. Surgery 127(1):112–114
17. Carter CR, McKay CJ, Imrie CW (2000) Percutaneous necrosectomy and sinus tract endoscopy in the management of infected pancreatic necrosis: an initial experience. Ann Surg 232(2): 175–180
18. Risse O, Auguste T, Delannoy P, Cardin N, Bricault I, Létoublon C (2004) Percutaneous video-assisted necrosectomy for infected pancreatic necrosis. Gastroenterol Clin Biol 28(10 pt 1):868–871
19. de la Fuente SG, Demaria EJ, Reynolds JD, Portenier DD, Pryor AD (2007) New developments in surgery: natural orifice transluminal endoscopic surgery (NOTES). Arch Surg 142(3):295–297
20. Isayama H, Yamamoto K, Mizuno S, Yashima Y, Togawa O, Kogure H, Sasaki T, Sasahira N, Nakai Y, Hirano K, Tsujino T, Tada M, Kawabe T, Omata M (2009) NOTES and endoscopic pancreatic necrosectomy for the GI endoscopist. J Hepatobiliary Pancreat Surg 16(3):270–273
21. Seifert H, Wehrmann T, Schmitt T, Zeuzem S, Caspary WF (2000) Retroperitoneal endoscopic debridement for infected peripancreatic necrosis. Lancet 356(9230):653–655
22. Seewald S, Groth S, Omar S, Imazu H, Seitz U, de Weerth A, Soetikno R, Zhong Y, Sriram PV, Ponnudurai R, Sikka S, Thonke F, Soehendra N (2005) Aggressive endoscopic therapy for pancreatic necrosis and pancreatic abscess: a new safe and effective treatment algorithm. Gastrointest Endosc 62(1):92–100
23. Voermans RP, Veldkamp MC, Rauws EA, Bruno MJ, Fockens P (2007) Endoscopic transmural debridement of symptomatic organized pancreatic necrosis. Gastrointest Endosc 66(5):909–916
24. Seifert H, Biermer M, Schmitt W, Jürgensen C, Will U, Gerlach R, Kreitmair C, Meining A, Wehrmann T, Rösch T (2009) Transluminal endoscopic necrosectomy after acute pancreatitis: a multicentre study with long-term follow-up (the GEPARD Study). Gut 58(9):1260–1266
25. Baron TH, Morgan DE (1997) The diagnosis and management of fluid collections associated with pancreatitis. Am J Med 102(6): 555–563
26. Ranson JH, Balthazar E, Caccavale R, Cooper M (1985) Computed tomography and the prediction of pancreatic abscess in acute pancreatitis. Ann Surg 201(5):656–665
27. Cahen D, Rauws E, Fockens P, Weverling G, Huibregtse K, Bruno M (2005) Endoscopic drainage of pancreatic pseudocysts: long-term outcome and procedural factors associated with safe and successful treatment. Endoscopy 37(10):977–983
28. Hookey LC, Debroux S, Delhaye M, Arvanitakis M, Le Moine O, Devière J (2006) Endoscopic drainage of pancreatic-fluid collections in 116 patients: a comparison of etiologies, drainage techniques, and outcomes. Gastrointest Endosc 63(4):635–643
29. Baron TH, Harewood GC, Morgan DE, Yates MR (2002) Outcome differences after endoscopic drainage of pancreatic necrosis, acute pancreatic pseudocysts, and chronic pancreatic pseudocysts. Gastrointest Endosc 56(1):7–17
30. Gardner TB, Chahal P, Papachristou GI, Vege SS, Petersen BT, Gostout CJ, Topazian MD, Takahashi N, Sarr MG, Baron TH (2009) A comparison of direct endoscopic necrosectomy with transmural endoscopic drainage for the treatment of walled-off pancreatic necrosis. Gastrointest Endosc 69(6):1085–1094
31. Hariri M, Slivka A, Carr-Locke DL, Banks PA (1994) Pseudocyst drainage predisposes to infection when pancreatic necrosis is unrecognized. Am J Gastroenterol 89(10):1781–1784
32. Gardner TB, Coelho-Prabhu N, Gordon SR, Gelrud A, Maple JT, Papachristou GI, Freeman ML, Topazian MD, Attam R, Mackenzie TA, Baron TH (2011) Direct endoscopic necrosectomy for the treatment of walled-off pancreatic necrosis: results from a multicenter U.S. series. Gastrointest Endosc 73(4):718–726
33. Mathew A, Biswas A, Meitz KP (2008) Endoscopic necrosectomy as primary treatment for infected peripancreatic fluid collections. Gastrointest Endosc 68(4):776–782
34. Gruber RP, Vistnes L, Pardoe R (1975) The effect of commonly used antiseptics on wound healing. Plast Reconstr Surg 55(4): 472–476
35. Howell JM, Chisholm CD (1992) Outpatient wound preparation and care: a national survey. Ann Emerg Med 21(8):976–981
36. Despond O, Fiset P (1997) Oxygen venous embolism after the use of hydrogen peroxide during lumbar discectomy. Can J Anaesth 44(4):410–413
37. Ijichi T, Itoh T, Sakai R, Nakaji K, Miyauchi T, Takahashi R (1997) Multiple brain gas embolism after ingestion of concentrated hydrogen peroxide. Neurology 48(1):277–279
38. Sherman SJ, Boyer LV, Sibley WA (1994) Cerebral infarction immediately after ingestion of hydrogen peroxide solution. Stroke 25(5):1065–1067
39. Dickson KF, Caravati EM (1994) Hydrogen peroxide exposure–325 exposures reported to a regional poison control center. J Toxicol Clin Toxicol 32(6):705–7014
40. Kalloo AN, Canto MI, Wadwa KS, Smith CL, Gislason GT, Okolo PI 3rd, Pasricha PJ (1999) Clinical usefulness of 3% hydrogen peroxide in acute upper GI bleeding: a pilot study. Gastrointest Endosc 49(4 Pt 1):518–521
41. Aoun E (2010) Endoscopic management of iatrogenic peripancreatic abscess. DAVE Project. http://daveproject.org/endoscopic-

management-of-iatrogenic-peripancreatic-abscess/2010-05-03/. Accessed 29 July 2012
42. Charnley RM, Lochan R, Gray H, O'Sullivan CB, Scott J, Oppong KE (2006) Endoscopic necrosectomy as primary therapy in the management of infected pancreatic necrosis. Endoscopy 38(9):925–928
43. Escourrou J, Shehab H, Buscail L, Bournet B, Andrau P, Moreau J, Fourtanier G (2008) Peroral transgastric/transduodenal necrosectomy: success in the treatment of infected pancreatic necrosis. Ann Surg 248(6):1074–1080
44. Kahaleh M, Shami VM, Conaway MR, Tokar J, Rockoff T, De La Rue SA, de Lange E, Bassignani M, Gay S, Adams RB, Yeaton P (2006) Endoscopic ultrasound drainage of pancreatic pseudocyst: a prospective comparison with conventional endoscopic drainage. Endoscopy 38(4):355–359
45. Baron TH (2007) Drainage of pancreatic fluid collections: is EUS really necessary? Gastrointest Endosc 66(6):1123–1125
46. Jürgensen C, Neser F, Boese-Landgraf J, Schuppan D, Stölzel U, Fritscher-Ravens A (2012) Endoscopic ultrasound-guided endoscopic necrosectomy of the pancreas: is irrigation necessary? Surg Endosc 26(5):1359–1363