Pancreatology 19 (2019) 658–664

Contents lists available at ScienceDirect

Pancreatology

journal homepage: www.elsevier.com/locate/pan

Predictors of outcome of percutaneous catheter drainage in patients with acute pancreatitis having acute fluid collection and development of a predictive model

Balaji L. Bellam [a], Jayanta Samanta [a], Pankaj Gupta [a], Praveen Kumar M [b], Vishal Sharma [a], Narendra Dhaka [a], Phulen Sarma [b], Gaurav Muktesh [a], Vikas Gupta [c], Saroj K. Sinha [a], Rakesh Kochhar [a, *]

[a] Department of Gastroenterology, Postgraduate Institute of Medical Education and Research, Chandigarh, India
[b] Department of Pharmacology, Postgraduate Institute of Medical Education and Research, Chandigarh, India
[c] Department of General Surgery, Postgraduate Institute of Medical Education and Research, Chandigarh, India

ARTICLE INFO

Article history:
Received 10 March 2019
Received in revised form
28 May 2019
Accepted 31 May 2019
Available online 8 June 2019

Keywords:
Acute pancreatitis
Acute necrotising pancreatitis
Percutaneous catheter drainage
Predictors of outcome
Nomogram

ABSTRACT

Background: Percutaneous catheter drainage (PCD) is effective initial strategy in the step-up approach of management of acute pancreatitis (AP). The objective of this study was to identify factors associated with outcomes after PCD and develop a predictive model.

Method and materials: In a prospective observational study between July 2016 and Nov 2017, 101 consecutive AP patients were treated using a "step-up approach" in which PCD was used as the first step. We evaluated the association between success of PCD (survival without necrosectomy) and baseline parameters viz. etiology, demography, severity scores, C-reactive protein (CRP), and intra-abdominal pressure (IAP), morphologic characteristics on computed tomography (CT) [percentage of necrosis, CT severity index (CTSI), characteristics of collection prior to PCD (volume, site and solid component of the collection), PCD parameters (initial size, maximum size, number and duration of drainage) and factors after PCD insertion (fall in IAP, reduction in volume of collection).

Results: Among 101 patients, 51 required PCD. The success rate of PCD was 66.66% (34/51). Four patients required additional surgical necrosectomy after PCD. Overall mortality was 29.4% (15/51). Multivariate analysis showed percentage of volume reduction of fluid collection ($p = 0.016$) and organ failure (OF) resolution ($p = 0.023$) after one week of PCD to be independent predictors of success of PCD. A predictive model based on these two factors resulted in area under curve (AUROC) of 0.915. Nomogram was developed with these two factors to predict the probability of success of PCD.

Conclusion: Organ failure resolution and reduction in volume of collection after one week of PCD are significant predictors of successful PCD outcomes in patients with fluid collection following AP

Introduction

Till late 1990's primary necrosectomy was considered the gold standard for the treatment of acute necrotising pancreatitis. However various studies demonstrated high morbidity and mortality rates with such an aggressive treatment [1–3]. The use of percutaneous catheter drainage (PCD) in patients with pancreatitis was first popularized by Freeny et al., in 1998 [4]. They demonstrated 47% necrosectomy free survival rate in patients undergoing PCD. Subsequently, multiple other studies have reported encouraging results with the use of PCD [5–9]. In the landmark PANTER trial, Van Santvoort et al. compared primary necrosectomy to a more conservative "step-up approach" in patients with infected necrotising pancreatitis [10]. The first step in the "step-up approach" was the use of catheter drainage (percutaneous or endoscopic), followed by videoscopic assisted retroperitoneal debridement (VARD) and if required open necrosectomy. This trial showed better survival with the step-up approach than with open necrosectomy. Two recent meta-analyses have reported success rates of 64% [11] and

* Corresponding author. Department of Gastroenterology, Postgraduate Institute of Medical Education and Research, Chandigarh, India.
E-mail address: dr_kochhar@hotmail.com (R. Kochhar).

https://doi.org/10.1016/j.pan.2019.05.467
1424-3903/

55.7% [12] respectively with use of PCD alone. PCD has, therefore, become the initial modality for treatment of infected pancreatic necrosis and helps avoid necrosectomy in a significant proportion of patients.

Although several studies have shown benefit of PCD, only a few studies have looked at the factors predicting success of PCD. Amongst the factors which have been studied in the literature to predict negative outcome with PCD are multiorgan failure (MOF) [13], amount of pancreatic necrosis, heterogeneous nature of fluid collection, higher CT severity index (CTSI), multiple infected collection [14] and higher mean CT density of necrotic fluid collection [15]. Most of these studies are retrospective in design and have not incorporated certain important factors such as intra-abdominal pressure (IAP), amount of solid component in the collection, size of the drainage catheter and number of drainage catheters placed. Hence this prospective study was planned to a) analyse the predictors of outcome of PCD in patients with AP who were managed with "step-up approach" and b) develop a predictive model based on these.

Material and methods

Study protocol

This was a prospective observational study conducted at a tertiary care centre in North India between July 2016 and Nov 2017. All patients more than 18 years of age with AP admitted to the medical or surgical gastroenterology divisions (Dr VG), were considered for inclusion. We excluded patients with prior PCD at the time of admission and patients who had undergone any prior endoscopic/radiological/surgical intervention for AP, pregnant females, patients with known chronic pancreatitis and those who did not provide a written informed consent. The study was approved by Institute's ethics board (INT/IEC/2016/2496) and we followed the guidelines of Indian Council Medical Research [16] & Helsinki Declaration for conducting a human study. Written informed consent was taken from all patients prior to enrollment in this study.

Patient management (Fig. 1)

AP was diagnosed as per the revised Atlanta classification and the severity was also stratified using these criteria [17]. All patients underwent detailed clinical assessment which included general physical examination, assessment of vital parameters, and were monitored for development of local complications, organ failure and sepsis. Severity of the pancreatitis at presentation was assessed by acute physiology and chronic health evaluation (APACHE II), bedside index for severity (BISAP) and systemic inflammatory response syndrome (SIRS) scores. Organ failure assessment was done according to modified Marshall scoring system for organ failure [18]. All patients received analgesics, intravenous fluid resuscitation and organ support as per requirement. In case of suspected infection (worsening clinical course and/or presence of air within the necrosis seen on CECT) and/or positive drain culture or extra pancreatic infection, antibiotics were administered. Contrast enhanced computed tomography (CECT) was done between day five and day seven after the onset of pain to see extent of necrosis and grade and to measure CT severity index (CTSI) [19]. Volume and solid component in the fluid collection(s) was estimated by transabdominal ultrasonography (USG) prior to drainage. Solid component of the fluid collection was estimated by a trained radiologist and patients classified as having less than and more than 30% solid component in the whole collection. The volume of the collection was calculated using the ellipsoid formula (π/6*L*B*H) Fig. 1 [20].

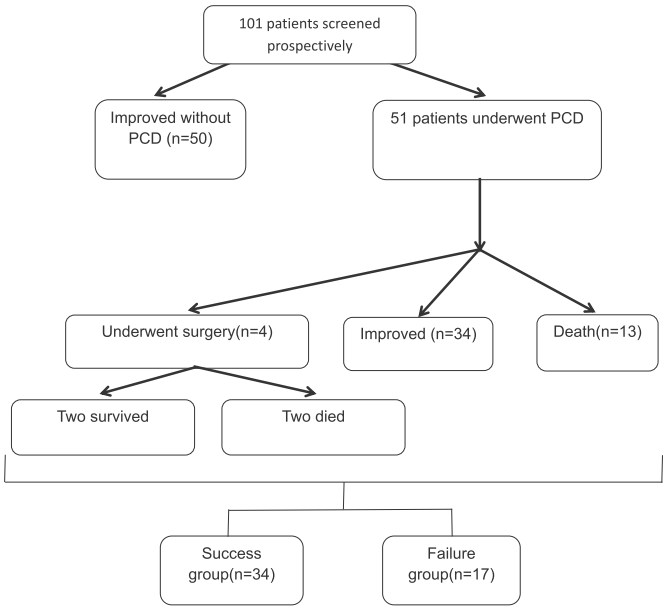

Fig. 1. Flow chart of the study.

Management of acute fluid collections

As part of step-up approach, PCD was inserted by a trained interventional radiologist (having > 5 years' experience in abdominal intervention) under image guidance (USG or CT). Choice of imaging guidance, the site and route were chosen by the radiologist in accordance with the site of collection, extent and amount of necrosis. The indications of PCD were sepsis, suspected or proven infection, persistent organ failure, symptoms due compression of adjacent organs (gastric, biliary) or uncontrolled pain), increase in size or number of collection(s) after initial conservative management. Initial size of catheter used for the drainage was 12–14 Fr and the fluid/material obtained was sent for microbiological analysis including cultures. Intraabdominal pressure, CRP levels, volume of collection and solid component in the collection on imaging were noted before PCD. After PCD insertion, drain was kept in the dependent position for gravity drainage. In addition, PCD catheter was flushed with 50 ml saline to maintain the patency two to three times a day using sterile precautions [21]. Extra saline was used to flush the PCD catheter depending upon the size of collection and a drain chart was maintained. Intra-abdominal pressure (IAP) was measured 6 hourly for 48 h after PCD and there-after once daily for 7 days and periodic assessment with complete blood count. Patients who had sterile collection before PCD and subsequently developed infection were put on intravenous antibiotics after the procedure. Such patients were continued on antibiotics till the clinical condition warranted.

Patients were monitored in high dependency areas or ICU. Patients with worsening of organ failure or sepsis, or inadequate drainage were evaluated by ultrasonography for upgradation of PCD catheter (up to 24 Fr) or additional PCD placement 48–72 h after the first PCD. Volume of collection was assessed by CECT abdomen or ultrasound after one week. Patients who were not improving with above treatment were considered for percutaneous endoscopic necrosectomy or surgical necrosectomy depending on clinical indication. Patients were discharged once they improved and followed up every 2–4 weeks for three months.

Complications

Complications of PCD like pain at the insertion site, blockade, and slippage or bleeding through the PCD were noted. International Study Group of Post-operative Pancreatic Fistulae [22] definition was used for external pancreatic fistulae (EPF). Patients with EPF were managed conservatively for 1–2 weeks and if EPF persisted, then patients underwent endoscopic retrograde cholangiopancreatography and pancreatic duct stenting. Other complications were managed accordingly.

Outcome of PCD

We defined success of PCD as patients who survived without surgical necrosectomy [13] and divided the patients into PCD "success" and "failure" groups. The parameters which were compared between the two groups included demographic criteria (age, gender, and etiology), disease severity criteria (CRP levels, organ failure, BISAP scores, and APACHE II scores), characteristics of the collection (volume, number, location and amount of solid component), CT characteristics (amount of necrosis and CTSI) and PCD parameters (timing, size of the initial catheter, maximum size, total number of catheters in individual patient, and total duration of drainage) and parameters following insertion of PCD (fall in IAP, reduction in the volume of collection).

Statistical analysis

Statistical analysis was performed using Statistical Product and Service Solutions version 23.0 (Chicago IL) and R software version 3.4.4. The additional packages which were used in R included rms, BootValidation, rmda, boot, DynNom, shiny and plyr [23–31]. Kolmogorov Smirnov test was used to check the normality of continuous variables. Mean and standard deviation were calculated for normally distributed variables, otherwise median and IQR were calculated. Categorical variables were presented in frequency and percentages. Independent *t*-test was applied to compare means of normally distributed variables between the two groups (PCD success and failure groups). For skewed variables Mann Whitney *U* test was applied to compare the medians. For categorical variables Chi square test/Fisher exact test was applied (as applicable).

To find out independent predictors for PCD success and failure, univariate analysis was performed. Significant variables in the univariate analysis were then taken for construction of binary logistic regression model. Results were presented as odds ratios (OR) with 95% confidence intervals (CI). A 2-tailed $P < 0.05$ was considered statistically significant. For internal validation of the obtained model, bootstrapping was done using 5000 resamples and a plot of the apparent & bias corrected curve was obtained. Area under the Receiver Operator Curve (AUROC) was performed to assess the predictive prowess of the model by taking the entire data. A nomogram was then constructed with the developed model using the rms package of R. [23] R shiny and DynNom package was used for the development of the interactive nomogram for the developed model [27,28].

Results

Patients and clinical outcomes

Among the enrolled 101 patients, 51 patients who underwent PCD as a primary intervention were included for analysis. The baseline parameters are represented in Table 1.

Table 1
Baseline data of 51 patients included in the study.

Parameter	Results
Age (years)	37.72 ± 11.98
Males (%)	37 (72.5%)
Etiology of pancreatitis	
Alcohol	25 (49%)
Gall stone disease	18 (35.3)
Alcohol + gall stone disease	4 (7.8%)
Others	4 (7.8%)
Severity parameters	
SIRS	3.45 ± 0.67
APACHE II score	8 (4)[a]
APACHE II score > 8	37.3%
CRP levels	246 (771)[a]
CT parameters	
CTSI score	8.23 ± 1.87
Site of collection	
Peripancreatic	24 (47.1%)
Distant peripancreatic	1 (2%)
Peripancreatic + distant	26 (51%)
Site of necrosis	
Pancreatic	2 (3.9%)
Extra pancreatic	1 (2%)
Pancreatic + extra-pancreatic	48 (94.1%)
Volume of collection before PCD (ml)	405 (515)[a]
Solid component in collection before PCD	34.40 ± 20.22
IAP before PCD (mm Hg)	16.70 ± 5.01
PCD parameters	
Number of PCD(s)	
One	24 (47.1%)
Two	20 (39.2%)
Three or more	7 (13.7%)
Interval between onset of pain and first PCD (days) (median, IQR)	20 (18)
First PCD size (Fr)	13.49 ± 2.22
Upgradation of first PCD	12 (23.5%)
Maximum size of first PCD (Fr)	14.58 ± 2.69
Cumulative size of all PCD (Fr) (median, IQR)	24 (16)
Total duration of PCD (days) (median, IQR)	46 (36)
Indications for PCD (n)	
Suspected/proven infection & organ failure	32 (62.74%)
Suspected/proven infection	11 (21.56%)
Organ failure	5 (9.80%)
Complications of PCD(n)	
EPF	4
GI fistulae	2
Minor bleed	1

[a] Median and IQR, SIRS: systemic inflammatory response syndrome, APACHE II: acute physiology and chronic health evaluation, CRP: C-reactive protein, CTSI: CT severity index, IAP: intra-abdominal pressure, n: number of patients, PCD: percutaneous catheter drainage, EPF: external pancreatic fistulae, GI: gastrointestinal.

PCD parameters

A total of 87 PCDs were inserted with a mean of 1.70 ± 0.80 PCDs per patient. Other PCD parameters (i.e. number of PCDs, maximum size of first and subsequent PCDs, total cumulative size of all PCD and duration of drainage of PCD) were comparable between the groups. The most common indication for the initial PCD was suspected/proven infection associated with organ failure in 32 (62.74%) patients followed by suspected or proven infection in 11 (21.56%), and organ failure in 5 (9.80%). The rest had multiple indications. Out of 51 patients, 34 (66.66%) had a sterile collection, and 17 (33.33%) had an infected collection. Catheter size upgradation was required in 19 (37.2%) patients. Four patients underwent surgery and a total of 15 deaths occurred including two patients who died after surgery. A two-way repeated measure ANOVA performed for assessing change in IAP following PCD between the time points (0, 6, 12, 24 and 48 h) with the outcome of the PCD (success or failure) was statistically not significant ($p = 0.730$) (supplementry Fig. 1). Overall mortality was 29.4% (n = 15/51) and

among these, 2 patients died in sterile group.

Complications

Of the 34 patients who had sterile cultures of the initial aspirate, 16 (47.05%) patients showed a subsequent growth of organisms(s). External pancreatic fistulae (n = 4), gastrointestinal fistulae (duodenal) (n = 2), and minor bleed from the drain (n = 1) were the other complications. Patients with EPF were considered for ERCP plus stenting. Transmural plastic stents were placed endoscopically for spontaneous duodenal fistulas and minor bleeds were managed conservatively.

Predictors of PCD success

Amongst 51 patients who underwent PCD, 34 (66.66%) patients had a successful PCD and 17 (33.33%) patients had failed PCD. On univariate analysis, 5 predictors of PCD success were found and are presented in Table 2. Other parametrs (i.e. APACHE II scores, CRP before PCD, hospital stay, and sterile vs infected collection) were comparable between the groups. Age and gender were added as predictors to multivariate analysis due to their clinical importance, though both did not show significance in univariate analysis. Though ICU stay showed significance in the univariate analysis it was not included in the multivariate analysis due to lack of relevance as a predictive factor. On multivariate analysis, percentage reduction in the volume of collection after PCD ($p = 0.016$) and organ failure resolution after PCD ($p = 0.023$) were found to be significantly different between the two groups (Table 3). Final logistic regression model was developed including volume of collection after PCD and organ failure resolution after PCD (supplementry table 1). The AUROC of the model was 0.915 (Fig. 2) and the developed model was validated internally by bootstrapping with 5000 re-samples and the validated AUC after bootstrap was 0.906 (Fig. 3). The optimism of bootstrap was 0.009 which shows that the AUC after bootstrapping of the model was almost similar to the AUC of the originally developed model. This demonstrates the model is not over fitted and is well predictive of the sample. A nomogram was developed for the constructed model (Fig. 4). A R shiny webserver containing the interactive nomogram of the developed model could be accessed at the following URL – https://gastropgiblbrk.shinyapps.io/PCDSuccess/

Discussion

"Step-up approach" is now the preferred method of managing infected pancreatic necrosis and acute fluid collections. As an initial step, percutaneous or endoscopic drainage is done followed by VARD/endoscopic necrosectomy. Surgical necrosectomy is reserved for cases with lack of improvement. Minimally invasive approaches have been shown to elicit a lesser inflammatory response when compared to surgical necrosectomy [32]. A recent randomized controlled study of endoscopic (EUS guided drainage followed by endoscopic necrosectomy) vs surgical (PCD followed by VARD) "step up approach" showed no difference in outcomes of infected pancreatic necrosis [33]. PCD is considered to be the initial step in management of collection at our centre. In a previous study we had a success rate around 60% in patients undergoing PCD [34]. Further, the placement of PCD is associated with reduction in levels of CRP and IL-6 [35]. PCD helps in removal of the pancreatic collection/necrosis and infected debris thereby controlling the inflammatory cascade and also decreasing IAP. This results in decreasing serum

Table 2
Comparison between successful and failed PCD groups.

		Success group (n = 34)	Failure group (n = 17)	P value
Onset of symptom to admission to hospital (days) (median, IQR)		9.0 (14.8)	20 (19.0)	0.280
Age (years) (mean ± SD)		37.52 ± 12.74	38.11 ± 10.68	0.87
Gender (males)		27 (58.8%)	10 (79.4%)	0.112[b]
Etiology of pancreatitis	Alcohol	17 (50)	8 (47.1%)	0.37[b]
	GSD	10 (29.4%)	8 (47.1%)	
	Both GSD and alcohol	3 (8.8%)	1 (5.9%)	
	others	4 (11.8%)	0	
APACHE II score (median, IQR)		8 (4.3)	8 (3.5)	0.349
CRP before PCD(mg/L) (median, IQR)		327 (968)	141 (443)	0.646
Hospital stay (days) (mean ± SD)		30.94 ± 12.23	35.41 ± 18.56	0.377
ICU stay (days) (median, IQR)		3.5 (10)	12 (20)	**0.042**[a]
MOF before PCD		1 (2.9%)	4 (23.5%)	**0.037**[a,b]
CTSI (median, IQR)		8 (4)	8 (3)	0.726
Amount of pancreatic necrosis	<30%	11 (32.4%)	3 (17.6%)	0.67[b]
	30–50%	7 (20.6%)	5 (29.4%)	
	>50%	15 (44.1%)	8 (47.1%)	
Site of collection	Peripancreatic	18 (52.9%)	6 (35.3%)	0.21[b]
	Extended peripancreatic	0	1 (5.9%)	
	Both	16 (47.1%)	10 (58.8)	
Gross volume of collection before PCD (ml) (median, IQR)		380 (547)	517 (483)	0.11
Solid component before PCD	>30%	14 (41.2%)	8 (47.1%)	0.458[b]
Volume of collection before PCD	≤750 ml	27	9	0.05[b]
OF resolution after PCD		31 (91.2%)	6 (35.3%)	**0.000**[a,b]
Percentage of volume reduction after PCD(mean ± SD)		74.35 ± 21.35	44.49 ± 31.02	**0.002**[a]
PCD parameters				
Number of PCD(median, IQR)		1.5 (1)	2.0 (2.0)	0.189
Day of first PCD(days)		19.5 (19.8)	20 (17)	0.992
First PCD size (Fr) (median, IQR)		14 (4)	12 (1)	**0.028**[a]
Maximum size of first PCD catheter (median, IQR)		14 (4)	14 (4)	0.534
Drainage duration of first PCD(days) (median, IQR)		46 (38.3)	38 (33.5)	0.07
Total cumulative size of all PCDs (Fr) (mean ± SD)		23.47 ± 9.67	26.11 ± 16.40	0.672

[a] Significant value.
[b] Chi square test/Fishers exact test, GSD: gall stone disease, APACHE II: acute physiology and chronic health evaluation, CRP: C-reactive protein, CTSI: CT severity index, OF: organ failure, MOF: multiorgan failure, ALI: acute lung injury, CVSF: cardiovascular failure.

Table 3
Multivariate analysis for prediction of PCD.

	Beta co-efficient	P value	OR	95% CI of OR
Age	−0.033	0.435	0.967	0.890–1.051
Gender	1.046	0.387	2.84	0.26–30.48
Multiorgan failure before PCD	0.363	0.818	1.43	0.066–31.44
Organ failure resolution after PCD	−3.788	**0.023**	0.023	0.001–0.589
Percentage of volume reduction of collection after PCD	0.050	**0.016**	1.05	1.009–1.094
Total volume of collection before PCD (750 ml cutoff)	0.039	0.976	1.040	0.082–13.15
First PCD size	0.576	0.133	1.77	0.840–3.76

PCD: percutaneous catheter drainage.

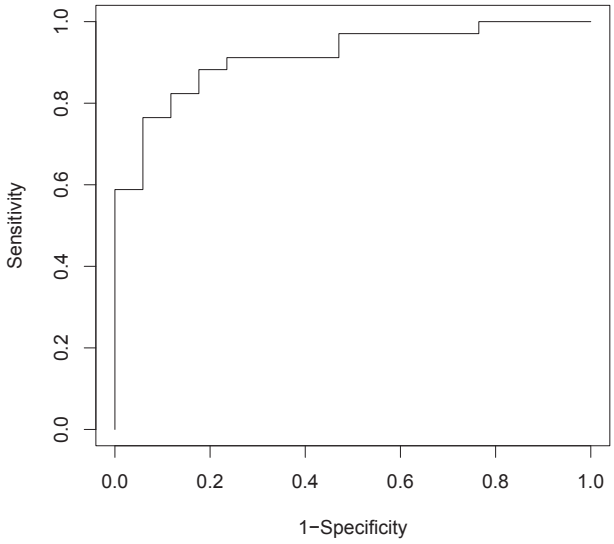

Fig. 2. Receiver operating characteristic curve of multivariable regression model for predicting PCD success in necrotising pancreatitis and area under curve is 0.915. Predictors are volume reduction and organ failure resolution after PCD.

inflammatory markers [36] which may postpone or even obviate need for surgical necrosectomy [6,21,37].

Success of PCD has been defined variably by different authors. Definitions used by different authors include survival without the need of surgical necrosectomy [13], drainage of collection without need for surgery [38], improvement after initial PCD without need for necrosectomy, major complication or death [39] and clinical deterioration in spite of PCD [40]. In our study, we defined success of PCD as survival without need for surgical necrosectomy [13].

Prediction of success or failure of PCD based approach is of importance so as to identify the subset of patients who require an aggressive approach at the outset. Further, identification of any modifiable factors (like the size or number of PCD) could help in improving the outcomes in these patients. This prospective study has identified the percentage volume reduction of fluid collection(s) following PCD and resolution of organ failure after PCD as predictors of PCD success. Interestingly the PCD related factors like size, number, and maximum size achieved did not seem to impact the outcomes in our patients. Also, the nature of collection (solid or liquid component and sterile or infected nature) or the site of collection did not affect the outcomes.

Measurement of IAP has gained increasing attention in the management and assessment of AP. However changes in IAP after PCD insertion did not seem to impact the outcomes. The findings of our study broadly suggest that neither the nature of collection nor the PCD related parameters affect the outcomes. This could be a consequence of the aggressive management wherein the patients were reassessed at third day for upsizing of the catheters or additional drain insertion. This may have rendered the initial catheter size and nature of collection meaningless as far as the final outcomes were concerned. However, our study does suggest the need for a dynamic assessment of patients who have undergone PCD for resolution of organ failure and reduction in size of collection so as to identify those who will have a successful outcome.

Different studies have looked into factors which might predict the outcome of PCD. In a couple of studies, mean density/heterogeneity of the collection on CT scan was reported to be a predictor of outcome.[13–15]Guo et al. reported that lower mean CT density of the necrotic fluid collection predicted improvement.[15]Holleman et al. and Li et al. found that heterogeneous collection on CT scan was a predictor of PCD failure [13,14]. We evaluated the solid component in fluid collection before PCD using ultrasonography. However we did not find any impact of amount of solid component on the PCD outcome. The reason for these findings could be related to the choice of imaging modality i.e. ultrasound rather than CT to quantify solid debris. Ultrasound is a better modality to determine the solid contents in a pancreatic collection whereas CT may identify only those collections which have extensive solid component [41]. Some studies also found other CT parameters like the percentage of necrosis, CTSI and multiple collections as predictors of PCD outcome [13,14,40]. However we did not find any significance for these parameters.

It is apparent from our study as also from other previous reports that organ failure is the driver of outcomes in patients with necrotising pancreatitis. Presence of MOF, as noted previously [13,40], seemed to predict worse outcomes in univariate analysis. However, resolution of organ failure after PCD was a strong predictor of PCD success [31 (91.2%) vs 6 (35.3%), $P = 0.018$)]. Some studies have reported that the size of collection does not affect the success of PCD drainage [39,40]; While our findings also support the contention that initial size of the collection does not predict the outcomes, however the percentage volume reduction after PCD emerged as a predictor of PCD success. Cao et al. [40] reported that reduction in volume of collection > 50% was a predictor of PCD success and Liu et al. [39] noted that volume reduction in successful group was 85.6% vs 21.8% in failure group ($p = 0.001$). We calculated the volume reduction at the end of 7 days after initial PCD insertion, while Cao et al. noted volume reduction at 3rd day and Liu et al. noted the collection at the end of 20 days. The reduction in size of the pancreatic collections is helpful in improving the outcomes by reduction in abdominal pressure, improvement in infection [21], and reducing the inflammatory response by decreasing interleukins/cytokines levels [35,39].

Finally, we constructed a prognostic nomogram with the percentage of volume reduction and organ failure resolution after PCD which were significant on multivariate analysis to detect the probability of successful PCD. We also designed a web page where

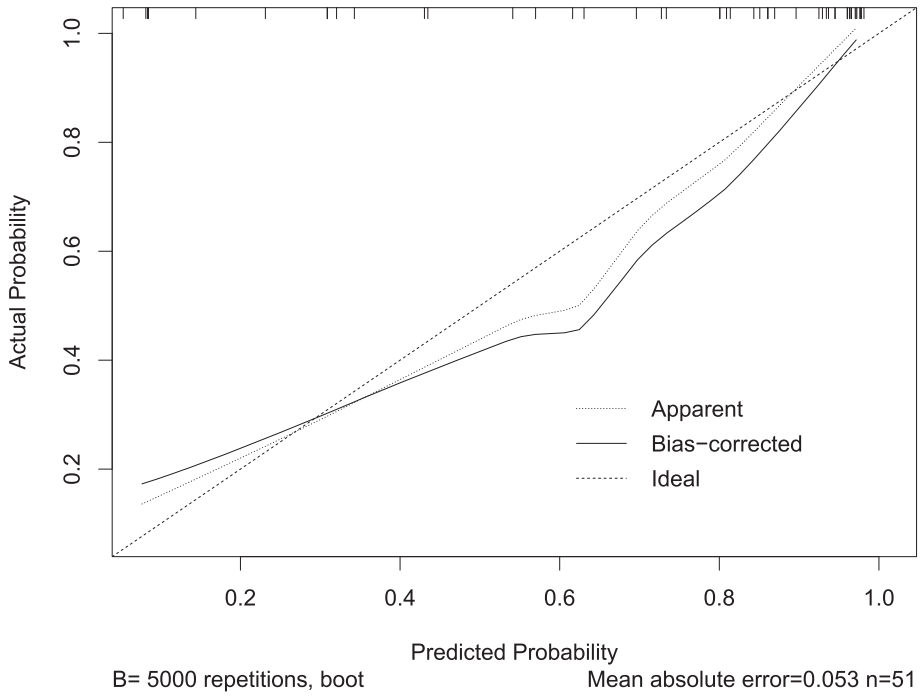

Fig. 3. Predictors of PCD success were volume reduction and organ failure resolution after PCD. Further internally validated by bootstrapping of 5000 resamples. The idle cure and bias corrected curve was close to each other.

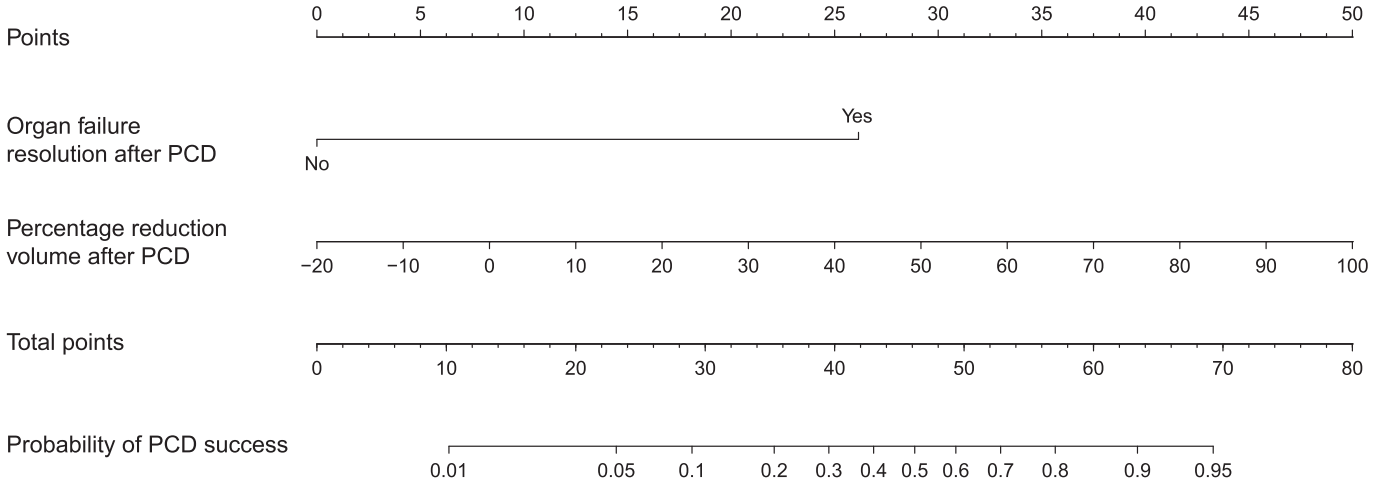

Fig. 4. Nomogram for predictor of PCD success in managing fluid collection in patients with necrotising pancreatitis. Total points line indicates total points obtained from predictors and which is synchronized with probability of PCD success line which indicate probability of PCD success. PCD, percutaneous catheter drainage.

the prediction could be done based on the model predictors. This would be helpful for external validation of the model by clinicians and researchers.

The limitations of our study include recruitment of patients from a single centre and a relatively smaller number of subjects. However, the study has important strengths which include a protocolised management of the pancreatic fluid collections, and evaluation of multiple parameters which could have affected success of the PCD including those related to the nature of collections and the PCD related factors.

To conclude, organ failure resolution and reduction in volume of collection after one week of PCD are significant predictors of successful PCD in patients with pancreatic fluid collection. Multi centric studies with larger sample size are required to validate this study.

Contributions

BLB: Acquisition and analysis of data and initial draft of the manuscript, Approval for final version.

JS: Initial draft of the manuscript, interpretation of data and approval of final version.

PG: Initial draft of the manuscript, interpretation of data and approval of final version.

PKM: Interpretation of data, its analysis, webserver design and approval of final version.

VS: Interpretation of data, its analysis and approval of final version.

ND: Acquisition and interpretation of data and approval of final version.

PS: Interpretation of data, its analysis and approval of final version.

GM: Interpretation of data and approval of final version.

SKS: Conception and design of study, intellectual content and approval of final version.

VK: Intellectual content and approval of final version.

RK: Conception and design of study, intellectual content, revision and approval of final version.

Conflicts of interest

The authors declare that they have no conflict of interest.

Acknowledgement

No conflict of interest and did not receive any funding for the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pan.2019.05.467.

References

[1] Tsiotos GG, Luque-de Leon E, Sarr MG. Long-term outcome of necrotizing pancreatitis treated by necrosectomy. Br J Surg 1998;85:1650–3.
[2] Rau B, Bothe A, Beger HG. Surgical treatment of necrotizing pancreatitis by necrosectomy and closed lavage: changing patient characteristics and outcome in a 19-year, single-center series. Surgery 2005;138:28–39.
[3] Rodriguez JR, Razo AO, Targarona J, et al. Debridement and closed packing for sterile or infected necrotizing pancreatitis: insights into indications and outcomes in 167 patients. Ann Surg 2008;247:294–9.
[4] Freeny PC, Hauptmann E, Althaus SJ, Traverso LW, Sinanan M. Percutaneous CT-guided catheter drainage of infected acute necrotizing pancreatitis: techniques and results. AJR American Journal of Roentgenology 1998;170:969–75.
[5] Fotoohi M, D'Agostino HB, Wollman B, Chon K, Shahrokni S, vanSonnenberg E. Persistent pancreatocutaneous fistula after percutaneous drainage of pancreatic fluid collections: role of cause and severity of pancreatitis. Radiology 1999;213:573–8.
[6] Baril NB, Ralls PW, Wren SM, et al. Does an infected peripancreatic fluid collection or abscess mandate operation? Ann Surg 2000;231:361–7.
[7] Bruennler T, Langgartner J, Lang S, et al. Outcome of patients with acute, necrotizing pancreatitis requiring drainage-does drainage size matter? World J Gastroenterol 2008;14:725–30.
[8] Mortele KJ, Girshman J, Szejnfeld D, et al. CT-guided percutaneous catheter drainage of acute necrotizing pancreatitis: clinical experience and observations in patients with sterile and infected necrosis. AJR Am J Roentgenol 2009;192:110–6.
[9] Rocha FG, Benoit E, Zinner MJ, et al. Impact of radiologic intervention on mortality in necrotizing pancreatitis: the role of organ failure. Arch Surg 2009;144:261–5.
[10] van Santvoort HC, Bakker OJ, Bollen TL, et al. A conservative and minimally invasive approach to necrotizing pancreatitis improves outcome. Gastroenterology 2011;141:1254–63.
[11] Mouli VP, Sreenivas V, Garg PK. Efficacy of conservative treatment, without necrosectomy, for infected pancreatic necrosis: a systematic review and meta-analysis. Gastroenterology 2013;144:333–340 e2.
[12] van Baal MC, van Santvoort HC, Bollen TL, et al. Systematic review of percutaneous catheter drainage as primary treatment for necrotizing pancreatitis. Br J Surg 2011;98:18–27.
[13] Hollemans RA, Bollen TL, van Brunschot S, et al. Predicting success of catheter drainage in infected necrotizing pancreatitis. Ann Surg 2016;263:787–92.
[14] Li A, Cao F, Li J, et al. Step-up mini-invasive surgery for infected pancreatic necrosis: results from prospective cohort study. Pancreatology 2016;16:508–14.
[15] Guo Q, Li A, Hu W. Predictive factors for successful ultrasound-guided percutaneous drainage in necrotizing pancreatitis. Surg Endosc 2016;30:2929–34.
[16] Icmr.nic.in. ETHICAL GUIDELINES FOR BIOMEDICAL RESEARCH ON HUMAN PARTICIPANTS [online] Available at: https://wwwicmrnicin/sites/default/files/guidelines/ethical_guidelines_0pdf. [Accessed 5 March 2019].
[17] Banks PA, Bollen TL, Dervenis C, et al. Classification of acute pancreatitis–2012: revision of the Atlanta classification and definitions by international consensus. Gut 2013;62:102–11.
[18] Marshall JC, Cook DJ, Christou NV, Bernard GR, Sprung CL, Sibbald WJ. Multiple organ dysfunction score: a reliable descriptor of a complex clinical outcome. Crit Care Med 1995;23:1638–52.
[19] Balthazar EJ, Robinson DL, Megibow AJ, Ranson JH. Acute pancreatitis: value of CT in establishing prognosis. Radiology 1990;174:331–6.
[20] Verguts J, Timmerman D, Bourne T, Lewi P, Koninckx P. Accuracy of peritoneal fluid measurements by transvaginal ultrasonography. UOG. the official journal of the International Society of Ultrasound in Obstetrics and Gynecology 2010;35:589–92.
[21] Besselink MG, van Santvoort HC, Nieuwenhuijs VB, et al. Minimally invasive 'step-up approach' versus maximal necrosectomy in patients with acute necrotising pancreatitis (PANTER trial): design and rationale of a randomised controlled multicenter trial [ISRCTN13975868]. BMC Surg 2006;6:6.
[22] Bassi C, Marchegiani G, Dervenis C, et al. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 Years after. Surgery 2017;161:584–91.
[23] Harrell Jr FE. Rms: regression modeling strategies. 2018.
[24] Martinez AJC. BootValidation: adjusting for optimism in 'glmnet' regression using bootstrapping. 2018.
[25] Brown M. Rmda: risk model decision analysis. 2018.
[26] Canty A, Ripley BD. Boot: bootstrap R (S-plus) functions. 2017.
[27] Jalali A, Roshan D, Alvarez-Iglesias A, Newell J. DynNom: dynamic nomograms for linear, generalized linear and proportional hazard models. 2017.
[28] Chang W, Cheng J, Allaire JJ, Xie Y, McPherson J. Shiny: web application framework for R. 2018.
[29] Wickham H. The split-apply-combine strategy for data analysis. J Stat Softw 2011;40:1–29.
[30] Wickham H. ggplot2: elegant graphics for data analysis. New York: Springer-Verlag; 2016.
[31] Davison AC, Hinkley DV. Bootstrap methods and their applications. Cambridge: Cambridge University Press; 1997.
[32] Bakker OJ, van Santvoort HC, van Brunschot S, et al. Endoscopic transgastric vs surgical necrosectomy for infected necrotizing pancreatitis: a randomized trial. JAMA 2012;307:1053–61.
[33] van Brunschot S, van Grinsven J, van Santvoort HC, et al. Endoscopic or surgical step-up approach for infected necrotising pancreatitis: a multicentre randomised trial. The Lancet 2018;391:51–8.
[34] Mallick B, Dhaka N, Gupta P, et al. An audit of percutaneous drainage for acute necrotic collections and walled off necrosis in patients with acute pancreatitis. Pancreatology 2018;18:727–33.
[35] Mallick B, Tomar S, Arora SK, Lal A, Dhaka N, Samanta J, et al. Change in serum levels of inflammatory markers reflects response of percutaneous catheter drainage in symptomatic fluid collections in patients with acute pancreatitis. JGH Open: An Open Acc J Gastroenterol Hepatol 2019;2019. article in press.
[36] Wang T, Liu LY, Luo H, et al. Intra-abdominal pressure reduction after percutaneous catheter drainage is a protective factor for severe pancreatitis patients with sterile fluid collections. Pancreas 2016;45:127–33.
[37] van Santvoort HC, Besselink MG, Bakker OJ, et al. A step-up approach or open necrosectomy for necrotizing pancreatitis. N Engl J Med 2010;362:1491–502.
[38] Horvath K, Freeny P, Escallon J, et al. Safety and efficacy of video-assisted retroperitoneal debridement for infected pancreatic collections: a multicenter, prospective, single-arm phase 2 study. Arch Surg 2010;145:817–25.
[39] Liu WH, Wang T, Yan HT, et al. Predictors of percutaneous catheter drainage (PCD) after abdominal paracentesis drainage (APD) in patients with moderately severe or severe acute pancreatitis along with fluid collections. PLoS One 2015;10:e0115348.
[40] Cao X, Cao F, Li A, et al. Predictive factors of pancreatic necrosectomy following percutaneous catheter drainage as a primary treatment of patients with infected necrotizing pancreatitis. Exp Ther Med 2017;14:4397–404.
[41] Rana SS, Chaudhary V, Sharma R, Sharma V, Chhabra P, Bhasin DK. Comparison of abdominal ultrasound, endoscopic ultrasound and magnetic resonance imaging in detection of necrotic debris in walled-off pancreatic necrosis. Gastro Rep 2016;4:50–3.