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A Combined Paging Alert and Web-Based Instrument Alters Clinician Behavior and Shortens Hospital Length of Stay in Acute Pancreatitis

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Abstract

OBJECTIVES—There are many published clinical guidelines for acute pancreatitis (AP).

Implementation of these recommendations is variable. We hypothesized that a clinical decision support (CDS) tool would change clinician behavior and shorten hospital length of stay (LOS).

METHODS—Design/Setting: Observational study, entitled, The AP Early Response (TAPER) Project. Tertiary center emergency department (ED) and hospital. Participants: Two consecutive

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CONFLICT OF INTEREST

Guarantor of the article: Matthew J. DiMagno, MD.

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samplings of patients having ICD-9 code (577.0) for AP were generated from the emergency department (ED) or hospital admissions. Diagnosis of AP was based on conventional Atlanta criteria. The Pre-TAPER-CDS-Tool group (5/30/06–6/22/07) had 110 patients presenting to the ED with AP per 976 ICD-9 (577.0) codes and the Post-TAPER-CDS-Tool group (5/30/06–6/22/07) had 113 per 907 ICD-9 codes (7/14/10–5/5/11). Intervention: The TAPER-CDS-Tool, developed 12/2008–7/14/2010, is a combined early, automated paging-alert system, which text pages ED clinicians about a patient with AP and an intuitive web-based point-of-care instrument, consisting of seven early management recommendations.

RESULTS—The pre- vs. post-TAPER-CDS-Tool groups had similar baseline characteristics. The post-TAPER-CDS-Tool group met two management goals more frequently than the pre-TAPER-CDS-Tool group: risk stratification ($P < 0.0001$) and intravenous fluids $> 6\text{L}/1\text{st } 0\text{--}24\text{ h}$ ($P = 0.0003$). Mean (s.d.) hospital LOS was significantly shorter in the post-TAPER-CDS-Tool group (4.6 (3.1) vs. 6.7 (7.0) days, $P = 0.0126$). Multivariate analysis identified four independent variables for hospital LOS: the TAPER-CDS-Tool associated with shorter LOS ($P = 0.0049$) and three variables associated with longer LOS: Japanese severity score ($P = 0.0361$), persistent organ failure ($P = 0.0088$), and local pancreatic complications (< 0.0001).

CONCLUSIONS—The TAPER-CDS-Tool is associated with changed clinician behavior and shortened hospital LOS, which has significant financial implications.

Acute pancreatitis (AP) is the most common gastrointestinal reason for hospitalization in the United States (1). Prolonged hospital length of stay (LOS) may occur in AP, which is associated with high hospital occupancy, increased costs, and adverse patient outcomes. Since hospital LOS is a key outcome and quality measure in AP, third-party payers and in-house utilization reviewers scrutinize records for variations in care of patients, which may increase LOS and costs. Consequently, a particularly useful instrument would enable key early management decisions that influence outcomes (e.g., shorten LOS).

There are many published clinical guidelines for the management of AP (2). Implementation of guideline recommendations is variable, however, possibly because the large number of guidelines leads to uncertainty about their use (2–4). It is also unclear whether recommendations can be successfully implemented or that they alter outcomes. Successful introduction of management guidelines requires development, dissemination, and implementation (5,6). The latter and critical arm of this process, the design of implementation strategies, is lacking from most management guidelines for AP (3).

Medical guideline implementation strategies include audit and audit-independent methods. Multiple retrospective and prospective audits (7–10), and national surveys (11–13) have been used to identify areas of noncompliance with guideline recommendations (7,8,10). Audits combined with intensive feedback modestly impact implementation of guideline recommendations in AP (14) and in other conditions (15), but is cumbersome methodology and unlikely to alter behavior of clinicians not under scrutiny. A real-time process that interfaces with clinical decisions during the delivery of care and meets the definition of a clinical decision support (CDS) (16) tool may have a broader and more immediate influence. E.g., a CDS system that automatically prompts users about specific management decisions

for diverse conditions (other than the exocrine pancreas) improved concordance with guideline recommendations in many but not all studies (17).

A premise of clinical medicine is that timely implementation of best practice or guideline recommendations will improve process of care and outcomes (5), but the impact of CDS tools on outcomes is inconsistent, understudied (17), and unknown in AP. Outcomes in AP, however, correlate with implementing specific guideline recommendations, such as enteral nutrition in those with predicted moderate-severe disease or hospital stay >7 days (18) and early endoscopic retrograde cholangiopancreatography (ERCP) (<72h) in patients with cholangitis or non-resolving obstructive jaundice (19). Strong evidence is lacking for two recommendations, including access to intensive care units (8,20) or “aggressive” fluid resuscitation (21).

We hypothesized that successful implementation of The AP Early Response (TAPER)-CDS-Tool (a combined early automated paging alert system and an intuitive web-based point-of-care instrument) would change clinician behavior, by increasing concordance with specific guideline recommendations for AP, and shorten hospital LOS. To test our hypotheses, we collected and analyzed data for two cohorts of patients with AP who presented to the ED, one before and one immediately following the development and activation of the TAPER-CDS-Tool. We then performed univariable and multivariable analyses to determine whether the TAPER-CDS-Tool reduces hospital LOS.

Methods

In 2008, we formed a multidisciplinary team of gastroenterologists, medical and surgical ICU directors and an ED physician to discuss variances in AP management, to determine the magnitude of institutional variances and to develop and implement quality improvement measures. The study, entitled The AP Early Response (TAPER) project, was approved by the University of Michigan Institutional Review Board as two separate studies (HUM00032206 and HUM00042702) corresponding to data collection for two separate case samples (see Pre-and Post-TAPER-CDS-Tool Case Samples). Based on a preliminary audit and consensus agreement about key guideline recommendations, we developed the TAPER-CDS-Tool (12/2008 to 05/2010), consisting of a combined early automated paging-alert system and intuitive web-based point-of-care instrument, which provides clinicians information for making key decisions when patients with AP present to the ED.

Selection of pre- and post-TAPER-CDS-tool case samples

Following development of the TAPER-CDS-Tool (see below), we conducted two separate IDX cross-sectional searches of our health system’s databases (Figure 1) to identify patients having an International Classification of Diseases 9th edition (ICD-9) code (577.0) for AP. Both searches were of approximately 1-year duration, a sufficient length of time to ascertain patients to meet sample size goals. The pre-TAPER-CDS-Tool search was from 5/30/2006 to 6/22/2007, which avoided overlapping with the TAPER-CDS-Tool development period, and the post-TAPER-CDS-Tool period was from 7/14/2010 to 5/20/2011.

Patient identification

The study team searched the electronic health record of patients with the ICD-9 code 577.0 generated from ED or hospital units to confirm the diagnosis of AP based on having two of three *a priori* criteria (3-fold increase in serum amylase or lipase, abdominal pain, and typical imaging evidence of acute pancreatitis) (22), and that these patients presented to the ED during the periods of the study and had no exclusion criteria (see Figure 1). Specifically excluded were patients with the diagnosis of chronic pancreatitis made by a clinical scoring system (23) that included imaging (calcification, Cambridge II, >5 abnormal EUS features) and/or abnormal function.

Variables and definitions

All study variables are defined in Supplementary Table 1 online.

The early automated paging alert system component of the TAPER-CDS-tool

ED clinicians were alerted by the automated paging alert system of the TAPER-CDS-Tool (Figure 2) when hyperamylasemia or hyperlipasemia (> threefold normal) was present in the electronic records of ED patients. The alert system pages the clinician by a text message about a possible diagnosis of AP and directs the clinician to the intuitive web-based point-of-care instrument named “PancMap”.

The website component of the TAPER-CDS-tool

The website PancMap, built with Dreamweaver CS4 software (Adobe Systems), has an intuitive management algorithm containing seven early management recommendations (Supplementary Table 1), formulated by consensus agreement among multidisciplinary faculty after discussing evidence from reviews (24–29) and clinical guidelines (20,30). These include diagnosis in the ED; assignment of etiology; early ERCP (<72h) for cholangitis or non-resolving obstructive jaundice; risk stratification in the ED (by any means but with emphasis on assessment of transient organ failure (30,31) and the clinical scoring systems SIRS criteria 2 (32) and BISAP score 3 (33)); triage to ICU for severe AP; intravenous (IV) fluid therapy (FT) > 250cc/h (> 6L/24h) using a resuscitation algorithm, and enteral feeding for predicted severe AP or prolonged hospital LOS.

To achieve the FT goal advocated by expert reviews (24–28) and a practice guideline (30), we developed an intuitive algorithm (Figure 2, bottom) modeled after goal-directed FT in sepsis/shock (34,35), and investigational protocols in AP (36) that mirror the structure of recently published protocols (37,38). The algorithm includes cautious FT in AP patients with preexisting organ failure, crystalloid boluses to achieve hemodynamic stability (26,34), and an initial FT maintenance rate of > 221ml/h or > 3cc/70kg/h that Wall *et al.* (39) reported in 2009 (in abstract form) that improves survival (39). Further FT boluses (34) and maintenance rate adjustments are based on hemodynamic stability and serial measures of blood urea nitrogen (BUN), a prognostic variable (33,40–43) and surrogate marker of adequate FT.

Data collection

Coinvestigators JPS, SG, TS, JC, MJD and EJW used methods identical to our previous studies (44) to use the search engine EMERSE (44) to examine the electronic health record for data of interest, to reconcile variations in the data recorded in the electronic health record, and to collect and tabulate data with Microsoft Excel (Microsoft, Redmond, WA) spreadsheets for data management. Data from nursing flow sheets were reviewed manually if vital signs and fluid volumes were not available electronically. To calculate values for clinical scoring systems (see Table 1), we used the most abnormal values during the first 0–24 h of presentation (45) and added no points for missing data (33,45).

Study outcomes

The primary outcome of the study was hospital LOS among patients alive at hospital discharge. In 39 patients awaiting cholecystectomy for gallstone AP, the LOS we used for study purposes was shortened to the preoperative day when the patient met three discharge criteria of minimal or no abdominal pain, a normal amylase and lipase or values less than threefold elevated and tolerating a soft or solid diet. The median shortening of LOS in days (interquartile range) by this method for patients undergoing cholecystectomy was not significantly different between the pre- and post-TAPER-CDS-Tool groups (2 (0–3) vs. 2 (1–5.75), $P=0.3704$).

Statistical analyses

Descriptive statistics were compiled on all variables to evaluate distributions prior to modeling. Categorical and dichotomous variables were assessed by χ^2 -tests or Fisher's exact test when necessary. Continuous variables were assessed using two sample t -tests for normally distributed variables and the Wilcoxon rank-sum test for non-parametric continuous data (Tables 1 and 2). To model hospital LOS as a continuous dependent variable (Table 3), data for LOS (days) were transformed to a normal distribution (by Johnson SI transformation (46) selected on the basis of having the lowest corrected Akaike's information criterion out of 11 transformation options (e.g., log normal, G log, etc.)). We performed univariable analysis for the association of each variable with LOS by determining the significance of its coefficient of determination (r^2) by one-way analysis of variance for dichotomous variables and by bivariate simple linear regression for continuous variables (Table 3, left panel). Multivariable standard least squares regression analysis (Table 3, right panel) included variables with $P < 0.2$ from the univariable analysis. The model was used to estimate the odds ratio and associated 95% confidence intervals. Statistical significance was defined as $P < 0.05$. Statistical analyses were performed using JMP version Pro 10 (SAS Institute, Cary, NC).

Sample size calculations

The study was designed to investigate whether the TAPER-CDS-Tool, the study "intervention" independently influenced LOS (a continuous variable). Based on mean (s.d.) LOS calculated for the pre-TAPER-CDS-Tool group of 108 consecutive patients with AP alive at discharge (Table 2B), we projected that a sample size of 99 per group had an 80 % power (alpha level < 0.05) to detect a hypothesized clinically important difference of 2 days

in LOS between the pre- and post-TAPER-CDS-Tool groups. We accrued consecutive AP patients in the post-TAPER-CDS-Tool group to match the pre-TAPER-CDS-Tool sample size.

Results

Characteristics of study subjects

The pre- and post-TAPER-CDS-Tool groups were similar (Table 1), including age, gender, severity (revised Atlanta criteria), etiologies of AP, alcohol use, cigarette smoking status, Charlson comorbidity score, BMI, antibiotic use, ICU care, ERCP, and surgery. Overall, 78.5 % ($N=175$) had mild AP, 13.0% ($N=29$) had moderate AP, and 8.5% ($N=19$) had severe AP, which compares to estimated frequencies of 80–85% for mild AP and 15–20% for severe AP (24,26,27,30) using older definitions of severity (47).

Effect of TAPER-CDS-tool on compliance with management goals

Two of the seven recommended early management goals for AP (Table 2A) were achieved more frequently in the post- vs. pre-TAPER-CDS-Tool groups: risk stratifying patients in the ED (28.3 vs. 4.5 %, $P<0.0001$) and administering IV FT >6 L/in the first 0–24 h of presentation (20.0 vs. 3.8 %, $P=0.0003$). Clinicians frequently established an early diagnosis of AP (90 %), assigned an etiology of AP (72 %) and performed early ERCP (<72 h) for cholangitis and non-resolving biliary obstruction (100%) but infrequently admitted patients from the ED to the ICU (1.8 % overall and 6.2 % with moderate-severe AP) or provided enteral nutrition (3.1% overall and 10.4% with moderate-severe AP).

Effect of TAPER-CDS-tool on outcomes

Hospital LOS was significantly shorter in the post- vs. pre-TAPER-CDS-Tool groups (Table 2B). The overall mean (s.d.) LOS was 4.6 (3.1) vs. 6.7 (7.0) days, $P=0.0126$. In mild AP, LOS was 4.0 (2.5) vs. 4.9 (3.0) days, $P=0.0113$ and in moderate-severe AP, LOS was 7.0 (3.9) vs. 14.5 (12.4) days, $P=0.0383$. The overall median (interquartile range) LOS was 4 (3–6) vs. 4.5 (3–8) days, $P=0.0126$. In mild AP, median (interquartile range) LOS was 3 (2–4) vs. 4 (3–6) days, $P=0.0113$ and in moderate-severe AP, LOS was 6 (5–8.5) vs. 11.5 (5–19.5) days, $P=0.0383$.

With univariable analysis, 11 variables associated with LOS ($P<0.05$; Table 3, left panel). The TAPER-CDS-Tool associated with shorter LOS and 10 variables associated with longer LOS. In multivariable standard least squares regression analysis, four independent variables out of 14 included in the model (based on having a P -value <0.2 in the univariable analysis) were associated with LOS (Table 3, right panel). The TAPER-CDS-Tool was associated with shorter LOS and three variables were associated with longer LOS: greater Japanese severity score, persistent organ failure and local pancreatic complications. Two of seven early management variables were excluded from multivariable analysis: admission from the ED to the ICU was excluded because of insufficient numbers ($N=4$ patients) and early ERCP <72 h because all patients in both groups with cholangitis or non-resolving biliary obstruction (Table 2A) had ERCP <72 h.

Discussion

The main Finding of this study was that the TAPER-CDS-Tool, the combined early automated paging alert system, and intuitive web-based point-of-care instrument, was associated with significantly shorter hospital LOS. The overall mean reduction of LOS was 2.1 days, 0.9 days for mild AP, and 7.5 days for moderate to severe AP, resulting in an overall reduction of 226.8 days LOS for the entire post-TAPER-CDS-Tool group of patients discharged from the hospital alive. Based on aggregate hospitalization costs of \$1,845/day for AP from the 2009 Nationwide Inpatient Sample (1), we estimate that implementation of the TAPER-CDS-Tool would reduce our annual institutional costs by 0.4 million dollars and annual costs in the United States by 1.06 billion dollars for 274,119 AP hospital discharges.

The second major finding was that the TAPER-CDS-Tool induced the clinicians to alter management of AP by increasing execution of two of seven recommended early management goals; risk stratifying patients in the ED and administering IV FT > 6 L within 0–24 h of presentation. These data corroborate observations from audits (7–10) and national surveys (11–13). In these reports, the guideline recommendations for managing AP that were variably implemented included early risk stratification (8), enteral feeding for patients with severe AP (13), and treating gallstones during the same hospital stay or at least within 2–4 weeks after onset of disease to avoid high readmission rates (7,9).

Compliance with clinical guidelines varies by level of expertise (11) but noncompliance may occur when recommendations are general, lack evidence and require resources that are not controlled or available to the practitioner (access to endoscopy, surgery, and ICU) (12). The intuitive design and immediate availability of the TAPER-CDS-Tool aided in real-time decisions made by clinicians actively managing AP and increased compliance of two of the seven-guideline recommendations.

No single guideline recommended goal, however, including the increased frequency of risk stratifying and administering IV FT > 6 L within the first 0–24 h, was significantly associated with LOS. This finding is consistent with observations that more frequent risk stratification does not directly affect outcomes (8) and “aggressive” FT has a postulated but unproven impact on outcomes (21). Because the definition and impact of “aggressive” FT are uncertain, we emphasize that persistent organ failure was not significantly greater in patients with predicted mild AP (based on Japanese severity score < 3) who received FT > 6 L vs. 6 L within the first 0–24 h (0/19 (0%) vs. 8/170 (4.7%) $P = 1.000$; data not shown). It is noteworthy that compliance after implementation of the TAPER-CDS-Tool for these recommendations was only 28.3% for risk stratification and 20% for administering IV FT > 6 L during the first 24 h. In contrast to compliance with individual guideline recommendations, execution of all of the top five most frequently implemented guideline recommendations (establishing an early diagnosis of AP, assigning an etiology of AP, performing early ERCP (< 72 h) for cholangitis and non-resolving biliary obstruction, risk stratifying patients in the ED and administering IV FT > 6 L within 0–24 h of presentation) was low in the pre- and post-TAPER-CDS-Tool groups (0.0 and 8.0 % (9 of 113); data not shown).

Three guideline recommendations that may improve outcomes in AP had a similar high or low frequency of implementation in the pre- and post-TAPER-CDS-Tool periods: access to an ICU (8,20) (rarely used), enteral nutrition (18) (rarely used) and early ERCP (< 72 h) (19) (always used). The infrequent use of ICU is explained by limited availability and high resource utilization (20) in a congested referral center hospital. Infrequent use of enteral nutrition is likely due to the combination of insufficient emphasis in the TAPER-CDS-Tool and not independently focusing on the interface with hospital providers (rather than ED clinicians) who are responsible for decisions regarding enteral feeding. Greater emphasis on enteral nutrition is required for future quality improvement efforts, but decisions to initiate certain treatments such as enteral nutrition rely on estimating LOS and severity.

Besides promoting increased implementation of some management guideline recommendations and an association with reduced LOS, we propose that the TAPER-CDS-Tool may also have less tangible but important effects such as fostering efficient and attentive care, and increasing unanimity among multidisciplinary teams. We cannot exclude that the decrease in hospital LOS in the post- vs. pre-TAPER-CDS-Tool time periods is due to a decline in LOS for AP in the United States, as between the years 1997–2003 (48), but we believe this is an unlikely explanation. Most importantly, serial data from the Nationwide Inpatient Sample indicates that median hospital LOS was stable (4.0) between the years 2000–2009 (1,49,50), which matches the overall median (interquartile range) LOS for AP in the pre-TAPER-CDS-Tool group (spanning 5/30/06–6/22/2007) and indicates that LOS for AP may have plateaued over the duration of this study. To extend the observations of the study and address the limitations of the observational study design, we plan to use the accrued pilot data to design a multicenter cluster randomized trial.

Automating prediction of LOS and severity of AP might facilitate key early management decisions that influence outcomes. Major determinants of LOS are known, such as persistent organ failure (32). However, the best predictor of LOS is unknown among scoring systems (Ranson and APACHE II), artificial neural network simulation and linear discrimination analysis (51,52). In a recent report (45), however, the Japanese severity score (42) had good and superior performance characteristics compared with other clinical scoring systems for predicting severe AP on admission and at the 48h. Similarly, we found by *post hoc* analyses that the Japanese severity score has a numerically greater correlation and predictive value, respectively, for hospital LOS and moderate-severe AP (Supplementary Table 2). In addition, four commonly available and independent variables might predict LOS and moderate-severe AP as well as six clinical scoring systems. The variables for LOS are temperature (°C), bicarbonate, white blood cell count, and Glasgow coma score, and for moderate-severe AP are heart rate, bicarbonate, white blood cell count, and creatinine (Supplementary Table 3). These data provide a rationale for automating the prediction of moderate-severe AP and LOS by using a few commonly available variables in the electronic medical record and a simple clinical scoring system (Glas-gow coma scale). Communicating these predictions to clinicians through a modified TAPER-CDS-Tool might enable key early management decisions, including IV fluids, ICU care, and enteral nutrition and further reduce LOS.

In summary, we demonstrate the successful implementation of an automated TAPER-CDS-Tool, consisting of a combined early automated paging alert system and an intuitive web-based point-of-care instrument, for application of AP clinical guidelines. The TAPER-CDS-Tool associated with changes in clinician behavior (reducing variations in recommended practice) and shortened hospital LOS, which has significant financial implications. Despite these changes associated with the TAPER-CDS-Tool, overall compliance with guideline recommendations for AP was low. It should be possible, however, with additional quality improvement efforts, to increase compliance for several recommendations that may significantly shorten LOS, particularly risk stratification and enteral nutrition. Eventually, prospective randomized studies will be required to validate our findings and to determine whether the TAPER-CDS-Tool compared with improvements of the TAPER-CDS-Tool (automation of risk stratification, greater emphasis on using enteral nutrition) influence clinician behavior and shorten hospital LOS.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Study Highlights

WHAT IS CURRENT KNOWLEDGE

- There are many published clinical guidelines for acute pancreatitis but implementation of these recommendations is variable.
- A premise of clinical medicine is that timely implementation of best practice or guideline recommendations will improve process of care and outcomes.

WHAT IS NEW HERE

- *The Acute Pancreatitis Early Response (TAPER) clinical decision support(CDS) Tool* is a combined early automated paging alert system and an intuitive web-based point-of-care instrument.
- The TAPER-CDS-Tool induced clinicians to alter management of acute pancreatitis by increasing execution of 2 (risk stratification in the emergency department and intravenous fluid resuscitation goals within 24 h) of 7 guideline recommendations.
- The TAPER-CDS-Tool was associated with a significant decrease in hospital length-of-stay.

Figure 1.
Methodological summary.

Emergency department early automated paging alert system

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Figure 2. The “TAPER-CDS-Tool”, which has two components: *The AP Early Response* (TAPER) automated paging alert system and an intuitive web-based point-of-care clinical decision support (CDS) instrument (PancMap). Reprinted from DiMagno *et al.* (53) (Copyright 2010, with permission from the Regents of the University of Michigan).

Table 1

Patient characteristics

Variable	TAPER-CDS-Tool		P value	Complete ^a Data (%)
	Pre- (%)	Post- (%)		
<i>Patients</i>	110	113		
Mean (s.d.) age, years	51.4 (17.4)	52.4 (18.1)	0.7005	100
Men	44 (40.0)	42 (27.2)	0.6819	100
Severity of acute pancreatitis			0.6272	100
Mild	88 (80.0)	87 (77.0)		
Moderate-severe	22 (20.0)	26 (23.0)		
Japanese severity score (0–24 h) > / = 3 ^b	15 (13.6)	12 (10.6)	0.5419	99 ^c
Etiology				100
Gallstone	41 (37.3)	50 (44.2)	0.3404	
Alcohol	17 (15.4)	14 (12.4)	0.5644	
Idiopathic	21 (19.1)	24 (21.2)	0.7402	
Other	31 (28.2)	25 (22.1)	0.3545	
Alcohol use status				99.6
Never drinker	56 (51.4)	57 (50.4)	Reference	
Current drinker	42 (38.5)	49 (43.4)	0.6735	
Former drinker	11 (10.1)	7 (6.2)	0.4498	
Cigarette smoking status				
Never smoking	50 (45.4)	39 (34.8)	Reference	99.6
Current smoking	38 (34.5)	54 (48.2)	0.0536	
Former smoking	22 (20.0)	19 (17.0)	0.8504	
Median (IQR) Charlson score ^d	1 (0–2)	1 (0–2)	0.9991	100
Mean (s.d.) BMI	27.8 (6.1)	29.0 (7.3)	0.1976	93.7
Antibiotics during hospitalization	49 (44.5)	41 (36.3)	0.2218	100
ICU care during hospitalization	8/110 (7.3)	8/113 (7.1)	1.0000	100
ERCP	9 (8.2)	14 (12.4)	0.3800	100
Surgery	21 (19.1)	24 (21.2)	0.7402	100
Cholecystectomy	19 (17.3)	20 (17.7)	1.0000	
Necrosectomy	0 (0)	2 (1.8)	0.4978	
Percutaneous drainage	2 (1.8)	3 (2.6)	1.0000	

AP, acute pancreatitis; BMI, body mass index; ERCP, endoscopic retrograde cholangiopancreatography; ICU, intensive care unit; IQR, interquartile range; s.d., standard deviation; TAPER, The Acute Pancreatitis Early Response.

^aPercentage of patients for whom complete data were available.

^bThe Japanese severity score (42) was selected to represent six clinical scoring systems (defined in Supplementary Table 1) on the basis of a recent multicenter study (45) for predicting severe AP and performance characteristics for predicting both moderate-severe AP and LOS in our data set (Supplementary Tables 2 and 3). To calculate values for clinical scoring systems, we analyzed the most abnormal values during the first 0–24 h of presentation (45) and added no points for missing data (33,45).

^cData was virtually always complete for 7 of 9 variables in the JPS clinical scoring system (99%) but two variables (LDH and C-reactive protein) were present in < 20% of patients.

^dStatistics: Wilcoxon rank sum test, otherwise *t*-test for continuous variables and Fisher's exact test for categorical variables.

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Table 2

Compliance with seven management goals and outcomes of AP

	TAPER-CDS-Tool		<i>P</i> value
	Pre- (%)	Post- (%)	
<i>A. Seven early management goals of AP</i>			
Early diagnosis in emergency department	96/110 (87.3)	105/113 (92.9)	0.1822
Assignment of etiology during hospitalization	76/110 (69.1)	81/113 (71.7)	0.7694
Early ERCP (< 72 h) indicated ^a	16 (14.5)	8 (7.1)	0.0855
Performed early ERCP or condition resolved	16/16 (100)	8/8 (100)	1.0000
Risk stratification in emergency department	5/110 (4.5)	32/113 (28.3)	< 0.0001
Mild acute pancreatitis	4/88 (4.5)	19/87 (21.8)	0.0007
Moderate-severe acute pancreatitis	1/22 (4.5)	13/26 (50.0)	0.0010
> 6 Liters IV fluid in first 0–24 h	4/106 (3.8)	22/112 (20.0)	0.0003
Mild acute pancreatitis	0/84 (0.0)	13/84 (15.5)	0.0001
Moderate-severe acute pancreatitis	4/22 (18.2)	9/26 (34.6)	0.3288
Admission from emergency department to ICU	3/110 (2.7)	1/113 (0.9)	0.3649
Enteral nutrition	2/110 (1.8)	5/113 (4.4)	0.4459
<i>B. Outcomes of AP</i>			
Local pancreatic complications	12/110 (10.8)	9/113 (8.0)	0.4979
Acute peripancreatic fluid collection (no necrosis)	7/110 (6.3)	5/113 (4.4)	0.5660
Necrosis	5/110 (4.5)	4/113 (3.5)	0.7461
Pancreatic necrosis	2/110 (1.8)	4/113 (3.5)	0.6834
Pancreatic and peripancreatic necrosis	3/110 (2.7)	0/113 (0)	0.1184
Transient organ failure	10/110 (9.0)	12/113 (10.6)	0.8223
Persistent organ failure	6/110 (5.4)	13/113 (11.5)	0.1493
Mortality	2/110 (1.8)	5/113 (4.4)	0.4459
Hospital LOS (non-deceased) in days ^b			
All severity			0.0126
Mean (s.d.)	6.7 (7.0)	4.6 (3.1)	
Median (IQR)	4.5 (3–8)	4 (3–6)	
Mild acute pancreatitis			0.0113
Mean (s.d.)	4.9 (3.0)	4.0 (2.5)	
Median (IQR)	4 (3–6)	3 (2–4)	
Moderate-severe acute pancreatitis			0.0383
Mean (s.d.)	14.5 (12.4)	7.0 (3.9)	
Median (IQR)	11.5 (5–19.5)	6 (5–8.5)	

AP, acute pancreatitis; CDS, clinical decision support; ERCP, endoscopic retrograde cholangiopancreatography; ICU, intensive care unit; IQR, interquartile range; LOS, length of stay (days) in hospital; s.d., standard deviation; TAPER, The Acute Pancreatitis Early Response.

^a Indications for early ERCP (< 72 h) are cholangitis or non-resolving biliary obstruction. In 24 patients with these conditions, resolution occurred and did not require early ERCP in 50% (8/16) of pre-TAPER-CDS-Tool vs. 0% (0/8) of the TAPER-CDS-Tool groups.

^bStatistics: Wilcoxon rank sum test; otherwise Fisher's exact test.

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Table 3

Univariable and multivariable analyses for hospital LOS among live hospital discharges

Variable	Univariable R ²	P value	Multivariable	
			OR	95% CI
Patient characteristics- investigational				
Age	0.0103	0.1370	1.00	1.00–1.01
Male gender	0.0183	0.0472	1.02	0.90–1.16
Etiology				
Other		Reference		
Gallstone	0.0035	0.0902	0.90	0.74–1.09
Alcohol	0.0027	0.6755		
Idiopathic	0.0125	0.0294	1.07	0.81–1.42
Alcohol use status				
Never drinker		Reference		
Current drinker	0.0146	0.0890	1.07	0.88–1.31
Former drinker	0.0047	0.4460		
Cigarette smoking status				
Never smoking		Reference		
Current smoking	0.0003	0.8307		
Former smoking	0.0404	0.0246	1.05	0.85–1.30
Median Charlson score	0.0064	0.2422		
BMI	0.0023	0.5018		
Combined TAPER-CDS-Tool ^a	0.0264	0.0168	0.84	0.75–0.95
Early diagnosis of AP in ED	0.0042	0.3458		
Assignment of etiology	0.0323	0.0081	1.17	0.99–1.38
Risk stratification in ED	0.0000	0.9219		
> 6L cumulative 24 h IV fluids	0.0207	0.0375	1.12	0.93–1.36
Enteral nutrition	0.0342	0.0064	1.18	0.81–1.73
Severity determinants and a predictor				

Variable	Univariable R ²	P value	Multivariable		
			OR	95% CI	P value
Transient organ failure	0.0570	0.0004	1.20	0.98–1.47	0.0855
Persistent organ failure	0.1011	<0.0001	1.37	1.09–1.74	0.0088
Local pancreatic complications	0.1401	<0.0001	1.54	1.26–1.90	<0.0001
Japanese severity score (0–24 h) ^b	0.1334	<0.0001	1.15	1.01–1.32	0.0361

AP, acute pancreatitis; BMI, body mass index; CDS, clinical decision support; CI, confidence interval; ED, emergency department; LOS, length of stay (days) in hospital; LC, local (pancreatic) complication; OR, odds ratio; POF, persistent organ failure; R², coefficient of determination; TAPER, The Acute Pancreatitis Early Response.

Statistics: Multivariable analysis was by standard least squares regression and included variables from the univariable analysis with $P < 0.2$.

^aTwo of seven early management variables were excluded from multivariable analysis: admission from the ED to the ICU was excluded because of insufficient numbers ($N=4$) and early ERCP < 72 h because all patients in both groups with cholangitis or non-resolving biliary obstruction had ERCP < 72 h.

^bThe Japanese severity score (42) was selected to represent six clinical scoring systems (defined in Supplementary Table 1) on the basis of a recent multicenter study (45) for predicting severe AP and performance characteristics for predicting both moderate-severe AP and LOS in our data set (Supplementary Table 2). To calculate values for clinical scoring systems, we analyzed the most abnormal values during the first 0–24 h of presentation (45) and added no points for missing data (33,45).