Abdominal Compartment Syndrome in Acute Pancreatitis

A Systematic Review

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Abstract: Abdominal compartment syndrome (ACS) is a lethal complication of acute pancreatitis. We performed a systematic review to assess the treatment and outcome of these patients.

A systematic literature search for cohorts of patients with acute pancreatitis and ACS was performed. The main outcomes were number of patients with ACS, radiologic and surgical interventions, morbidity, mortality, and methodological quality.

After screening 169 articles, 7 studies were included. Three studies were prospective and 4 studies were retrospective. The overall methodological quality of the studies was moderate to low. The pooled data consisted of 271 patients, of whom 103 (38%) developed ACS. Percutaneous drainage of intraabdominal fluid was reported as first intervention in 11 (11%) patients. Additional decompressive laparotomy was performed in 8 patients. Decompressive laparotomy was performed in a total of 76 (74%) patients. The median decrease in intraabdominal pressure was 15 mm Hg (range, 33–18 mm Hg). Mortality in acute pancreatitis patients with ACS was 49% versus 11% without ACS. Morbidity ranged from 17% to 90%.

Abdominal compartment syndrome during acute pancreatitis is associated with high mortality and morbidity. Studies are relatively small and have methodological shortcomings. The optimal timing and method of invasive interventions, as well as their effect on clinical outcomes, should be further evaluated.

Key Words: acute pancreatitis, necrotizing pancreatitis, abdominal compartment syndrome, intraabdominal hypertension, decompression, surgery

(*Pancreas* 2014;43: 665–674)

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Received for publication July 4, 2013; accepted January 12, 2014.

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Sandra van Brunschot is sponsored by the Dutch Maag Lever Darm Stichting and Fonds NutsOhra to perform clinical studies on necrotizing pancreatitis. The sponsors had no involvement in any stage of the study design, data collection, data analysis, and interpretation of the study results. The authors declare no conflict of interest.

Author Contributions: *Study design*: SvB, HvS, MGB, and MAB. *Literature search and study selection*: SvB and AJS. *Analysis plan design and statistical analysis*: SvB, AJS, and HvS. *Drafting of the article*: SvB. *Data access and responsible for the integrity of the data and the accuracy of the data analysis*: SvB and AJS. *Correction and approval of the final article*: All authors.

Supplemental digital contents are available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.pancreasjournal.com).

Acute pancreatitis runs a severe course in around 20% of patients and is associated with a mortality rate of 8% up to 39%.[1] The most lethal complication in the course of severe acute pancreatitis is abdominal compartment syndrome (ACS). Abdominal compartment syndrome is defined by the World Society of Abdominal Compartment Syndrome (WSACS) as a life-threatening sustained elevation of the intraabdominal pressure (IAP) that is associated with new onset organ failure or acute worsening of existing organ failure.[2] Symptoms of ACS include a tensely dilated abdomen, oliguria, and increased peak airway pressure.[3,4] Intraabdominal pressure is preferably determined using a transurethral probe inserted in the urinary bladder (the transbladder technique).[2,4,5] A summary of the 2013 updated WSACS evidence-based guidelines is shown in Table 1.[2]

The pathophysiology of ACS in acute pancreatitis is thought to be directly related to the inflammation of the pancreas. This inflammation starts a cascade of pancreatic and visceral edema, acute peripancreatic fluid collections, capillary leakage causing ascites, paralytic ileus, and gastric dilatation by upper gastrointestinal tract obstruction leading to an elevated IAP.[6–8] An elevated IAP generally occurs relatively early (often within the first week) after onset of severe acute pancreatitis.[3,9] Abdominal compartment syndrome can also be the result of overly aggressive fluid resuscitation, and sometimes, large peripancreatic collections play a role.[10] Abdominal compartment syndrome can lead to reduced perfusion and subsequent ischemia of intraabdominal organs followed by further progression of the existing organ failure leading to a potentially lethal downward spiral.[5,8] The most affected organs by ACS are the lungs and kidneys.[4]

Because acute pancreatitis is a well-established risk factor for ACS, the 2013 WSACS guidelines recommend routinely measuring of IAP in critically ill patients with acute pancreatitis.[2] The diagnosis of ACS in severe acute pancreatitis is difficult because symptoms may resemble those of other complications, such as systemic inflammatory response syndrome, acute respiratory distress syndrome, infected necrosis, and multiple organ dysfunction syndrome.[4]

In daily practice, many patients with ACS undergo decompressive laparotomy, which obviously has a risk of complications. Therefore, numerous medical, nonmedical, and minimally invasive therapies have been introduced. Several authors, including the 2013 WSACS guidelines, advise percutaneous catheter drainage as the first step of invasive intervention[2,7,9] to potentially obviate the need for decompressive laparotomy.[2]

Various observational cohort studies on ACS in acute pancreatitis have been reported in recent years but much remains unknown about incidence, diagnosis, clinical course, and optimal treatment. The aim of current study was to evaluate the published cohorts on ACS in acute pancreatitis for methodological limitations, differences in patient populations, treatment strategies, and outcome.

METHODS

Study Selection

We adhered to the preferred reporting items for systematic reviews and meta-analyses guidelines for reporting on meta-analyses and systematic reviews.[11] A systematic literature search from 1993 (publication of the Atlanta classification for acute pancreatitis[12]) to April 2013 was performed in the PubMed, Embase, and the Cochrane Library according to a protocol designed before data collection. Only articles in English language were included. The search terms are provided in Supplemental Digital Content Appendix 1 (http://links.lww.com/MPA/A297).

All titles and abstracts of studies identified by the initial search were screened to select those reporting on ACS in patients with acute pancreatitis. We excluded duplicate references and studies reporting the same data. Subsequently, full-text articles of the selected studies were screened independently by 2 authors to assess eligibility. All cross-references were screened for potentially relevant studies not identified by the initial literature search. The final decision on eligibility was reached by consensus among all authors.

The inclusion criteria were as follows:

- a consecutive cohort of at least 30 patients with acute pancreatitis that includes a subgroup of patients with ACS; or
- a consecutive cohort of at least 10 patients with acute pancreatitis and ACS.

The exclusion criteria were as follows:

- no data available on treatment strategy for ACS, morbidity, and mortality;
- no data available on the subgroup of patients with ACS; or
- cohort including chronic pancreatitis (and results for acute pancreatitis not reported separately).

The cutoffs for minimal cohort sizes were arbitrarily chosen. We also performed a systematic search for ongoing randomized controlled trials on ACS in the World Health Organization International Clinical Trials Registry Platform (http://apps.who.int/trialsearch/), which includes data from 15 national and international trial registries. We used the search terms *abdominal compartment syndrome*, *intraabdominal hypertension*, *intraabdominal pressure*, and *decompressive laparotomy* (search date May 16, 2013).

Assessment of Study Quality

All included studies were assessed for quality using 3 previously validated checklists that scored the methodological quality of nonrandomized studies.[13–15] Downs and Black[13] described a checklist with 27 items that can be used for quality assessment for both randomized and nonrandomized studies. The methodological index for non-randomized studies (MINORS) checklist contains 8 items for noncomparative studies and 12 items for comparative studies.[14] MacLehose et al[15] used a modified Downs and Black[13] checklist, which consists of 29 items. In all 3 lists, a low score reflects a high risk of bias, whereas a high score reflects a low risk of bias. To facilitate comparison of these checklists, each score was converted to a score on a 0 to 10 scale as previously reported.[16] No studies were excluded based on their score. The mean of the 0 to 10 scales of all 3 checklists was calculated to determine methodological quality. We

TABLE 1. Summary of the 2013 ACS Guidelines

	Evidence-Based Guidelines From the 2013 WSACS[2]
Definitions	IAP: the steady-state pressure concealed within the abdominal cavity
	IAH: a sustained or repeated pathologic elevation in IAP of ≥12 mm Hg
	ACS: a sustained IAP of >20 mm Hg (with or without an abdominal perfusion pressure of <60 mm Hg) that is associated with new organ dysfunction/failure
Measurement method	Recommendations:
	1. Measure the IAP when any known risk factor for IAH/ACS is present in a critically ill or injured patient
	2. The standard IAP measurement technique should be the transbladder technique. Intraabdominal pressure should be measured at end expiration in the supine position and expressed in millimeters of mercury
Noninvasive treatment	Suggestions:
	1. Optimal pain and anxiety relief
	2. Brief trials of neuromuscular blockade as a temporizing measure
	3. Consider the potential contribution of body position to elevated IAP
	4. Liberal use of enteral decompression
	5. Neostigmine, used for the treatment of established colonic ileus
	6. Avoid a positive cumulative fluid balance after the acute resuscitation
Minimal invasive treatment	Suggestions:
	Use PCD to remove (obvious intraperitoneal) fluid (when technically feasible) as first step of treatment
Invasive treatment	Recommendations:
	Decompressive laparotomy as second step of treatment in cases of overt ACS
Postoperative management	Recommendations:
	1. Obtain an early or at least same-hospital-stay abdominal fascial closure in ICU patients with open abdominal wounds
	2. Strategies using negative-pressure wound therapy should be used in patients with open abdominal wounds

PCD indicates percutaneous catheter drainage.

defined high methodological quality as a score higher than 8, moderate quality as a score of 6 to 8, moderate-to-low quality as a score of 4 to 6, and low quality with a score lower than 4.

Data Extraction

The following variables were extracted, where available, from the included articles: number of patients with ACS, definition of ACS used, method of IAP measurement, age, sex, etiology, predictive severity scores (eg, Imrie/modified Glasgow score and Acute Physiology and Chronic Health Evaluation [APACHE] II score), organ failure and intensive care unit (ICU) admission before intervention, computed tomography (CT) severity scores (CT severity index,[17] modified CT severity index,[18] and Balthazar grade[19]), time between hospital admission and occurrence of ACS, IAP, interval between elevated IAP and ACS, interval between elevated IAP and intervention, type of intervention for decompression, total number of interventions, success of intervention on lowering IAP and improving outcome, total length of ICU and hospital stay, complications, and mortality.

The data were extracted for calculation of mortality as primary outcome measure. The numerator for calculation was represented by the number of patients who died. The denominator was represented by the total number of patients with ACS and acute pancreatitis.

Data Analysis

The data were analyzed and reported to describe methodological quality, characteristics of included studies, patient characteristics, and outcome. The baseline characteristics were assessed to determine whether selection bias might have played a role in the outcome of ACS.

Statistical Analysis

Descriptive statistics were used to describe baseline characteristics and outcome variables for all studies separately and for the pooled data. To pool the data of continuous outcomes in systematic reviews, the mean values are needed. Published studies, however, often only report median, range, and sample size. Hozo et al[20] described a method to calculate the mean using the values of the median, and low and high end of the range. Using this method, we were able to present all data as means and calculated weighted means. Comprehensive Meta-analysis version 2 (Borenstein M, Hedges L, Higgins J et al; Biostat, Englewood, NJ, 2005) was used to generate a forest plot and I^2 to assess the heterogeneity of the results. The I^2 statistic indicates the proportion of total variation among the effect estimates attributed to heterogeneity rather than sampling error and has the advantage of being intrinsically independent of the number of studies. When the test of heterogeneity was not significant ($P > 0.05$) and I^2 was less than 30%,[21,22] significant heterogeneity was ruled out.

RESULTS

Literature Search

After removing duplicates, the systematic literature search identified 169 potentially relevant articles. The study selection flow chart is shown in Figure 1. Of the 169 articles, 162 were excluded after reviewing title, abstract, and full-text for the following reasons: non-English articles (n = 37), cohorts of patients also including carcinoma, chronic pancreatitis, pancreatic pseudocysts, or pancreatic tuberculosis and results of these subgroups were not reported separately (n = 10), cohorts of patients with no information on ACS (n = 14), cohorts with fewer than 30 patients with acute pancreatitis or fewer than 10 patients with acute pancreatitis and ACS (n = 16), cohorts

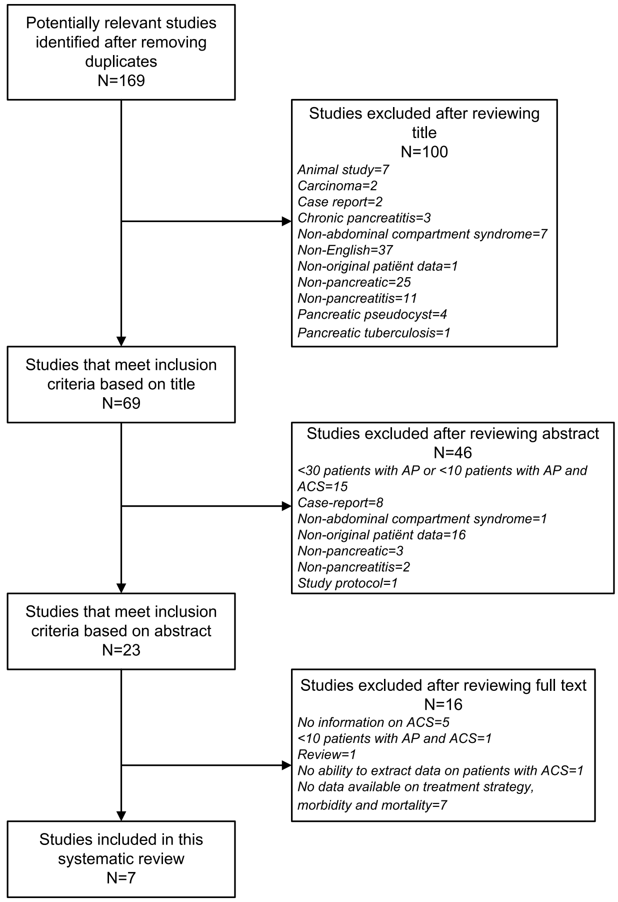

FIGURE 1. Study selection flow chart.

with solely nonpancreatic disease (n = 28), or patients with no pancreatitis (n = 13), cohorts who did not report 1 or more essential outcome (ie, no data on treatment strategy, morbidity, or mortality; n = 7), and cohorts excluded because of other reasons (eg, unable to retrieve IAP, reviews, animal studies or case reports; n = 37).

The systematic search for (ongoing) randomized controlled trials identified 1 relevant study (ClinicalTrials.gov, NCT00793715).[23] This DECOMPRESS trial is a multicenter study comparing percutaneous catheter drainage with decompressive laparotomy in patients with ACS during severe acute pancreatitis.

Study Characteristics

In total, 7 studies were included in this systematic review.[3,7,9,24–27] The study characteristics are summarized in Table 2.

There were no randomized controlled trials. Three studies were prospective observational cohort studies[3,24,27] and 4 studies were retrospective observational cohort studies.[7,9,25,26] From 4 studies, a selection of the reported cohort was included because this subgroup had ACS, fulfilled the selection criteria, and the outcomes were reported separately.[3,9,24,25] Four studies used the definition of ACS proposed by the 2013 WSACS guidelines, one study used a different definition, and 2 studies did not report definitions used.

Methodological Quality

The quality scores are shown in Table 3. There were no studies that scored high on methodological quality. Two studies

TABLE 2. Characteristics of the Included Studies

Authors	Country	Year	Study Design	Inclusion Criteria	Technique Used	Total No. Patients	No. Patients With ACS	Study Period (mo)
Bezmarevic et al[24]	Serbia	2012	Prospective observational cohort	Acute pancreatitis (APACHE II score ≥8 and CRP ≥120 mg/L) ACS (IAP >20 mm Hg and new organ dysfunction)	Decompressive laparotomy, percutaneous abdominal decompression and drainage	51	6	2009–2010 (14)
Chen et al[9]	China	2008	Retrospective cohort	Acute pancreatitis (Atlanta criteria) ACS (criteria of the WSACS)	Enterokinesia, percutaneous abdominal decompression and drainage and/or decompressive laparotomy	74	20	2002–2006 (48)
Davis et al[25]	Canada	2013	Retrospective cohort	Acute pancreatitis (Atlanta criteria) ACS (IAP >20 mm Hg associated with acute organ failure)	Decompressive laparotomy	45	16	2005–2009 (48)
De Waele et al[3]	Belgium	2005	Prospective observational cohort	Severe acute pancreatitis (Atlanta criteria) ACS (no definition reported)	Decompressive laparotomy	44	4	2000–2004 (52)
Leppäniemi et al[26]	Finland	2011	Retrospective cohort	Severe acute pancreatitis (Atlanta criteria) ACS (no definition reported)	Subcutaneous linea alba fasciotomy	10	10	nr
Mentula et al[7]	Finland	2010	Retrospective cohort	Severe acute pancreatitis (Atlanta criteria) ACS (IAP >20 mm Hg and new organ dysfunction)	Surgical decompression	26	26	2002–2007 (60)
Tao et al[27]	China	2003	Prospective observational cohort	Severe acute pancreatitis (diagnostic criteria Chinese Medical Association [1996]) ACS (Banks and Freeman[1])	Surgical decompression	21	21	1998–2003 (55)

nr indicates not reported.

TABLE 3. Methodological Quality of the Included Studies

Authors	MINORS Checklist	0–10	Checklist for Nonrandomized Trials	0–10	MacLehose Checklist	0–10	Mean MINORS, Downs, and MacLehose Checklist
Bezmarevic et al[24]	6	3.8	13	4.6	24	6.0	4.8
Chen et al[9]*	12	5.0	19	6.8	28	7.0	6.3
Davis et al[25]*	12	5.0	18	6.4	30	7.3	6.2
De Waele et al[3]*	10	4.6	14	5.0	25	6.2	5.3
Leppäniemi et al[26]	2	1.3	7	2.5	15	3.7	2.5
Mentula et al[7]	3	1.9	10	3.6	22	5.5	3.7
Tao et al[27]	1	0.6	4	1.4	13	3.2	1.7

*Comparative study.

scored moderate,[9,25] 2 studies scored moderate to low,[3,24] and 3 studies scored low.[7,26,27]

Patient Characteristics

The included studies comprised a total of 271 patients with acute pancreatitis and 103 patients with acute pancreatitis and ACS. The number of patients per study ranged from 10 to 74. Three studies included only patients with acute pancreatitis and ACS.[7,26,27] The other 4 studies were cohorts of patients with acute pancreatitis with a subgroup of patients who developed ACS. One study included 21 patients with ACS but described 23 ACS episodes because 2 patients had a recurrent episode of ACS.

Patient characteristics of the individual studies are shown in Table 4. The weighted means of baseline characteristics are given in Table 5. Three studies did not report patient characteristics on the subgroup of patients with ACS but for the entire cohort or a selection of patients with intraabdominal hypertension (IAH).[3,9,24] A total of 74% of all patients were male, and the mean age was 53 years. Six studies (146/271 patients) reported on etiology, which was alcoholic in 56 (38%) patients, biliary in 53 (36%) patients, hyperlipidemia in 15 (10%) patients, iatrogenic in 5 (3%) patients, and of other origin in 17 (8%) patients. The mean follow-up was 51 months (Table 2).

Of the 7 studies, 5 (67/103 patients) reported APACHE II scores. The mean APACHE II score was 18. All 7 studies reported organ failure. However, different definitions for organ failure were used. Five studies (76/103 patients) reported ICU admission, and all patients in these studies were admitted to the ICU. Seven studies reported the IAP. The mean IAP 24 hours after admission was 28 mm Hg. The difference in IAP between patients with acute pancreatitis and ACS and patients with acute pancreatitis without ACS was not reported. The prevalence of IAH was reported in all studies; the overall prevalence was 66% (149/226 patients). The overall study prevalence of ACS in the included cohorts was 38% (103/271 patients). Three studies reported only patients with acute pancreatitis and ACS. When these studies were excluded, the study prevalence of IAH and ACS was 54% (92/169 patients) and 22% (46/214 patients), respectively. There was significant heterogeneity for prevalence (I^2 = 76%, P = 0.006). The average number of days between diagnosis of ACS and first intervention was less than 1, as was reported in 5 studies.

Outcome

The clinical outcome of patients with acute pancreatitis and ACS in the individual studies is shown in Table 6 and the calculated weighted means in Table 5.

Of the 103 patients with ACS, 87 (84%) underwent an invasive intervention; this was reported in all studies. The type of first intervention was reported in 6 studies and was percutaneous catheter drainage of intraabdominal fluid in 11 (13%) patients and surgical decompression in 76 (87%) patients. No operation was performed in 16 (16%) of the 103 patients with ACS. In 8 (73%) patients with percutaneous drainage as first intervention, additional surgical decompression was necessary. Surgical decompression consisted of a full-thickness midline laparotomy (n = 66), a subcutaneous linea alba fasciotomy (n = 17), or full-thickness transverse bilateral subcostal laparotomy (n = 1). Patients underwent a median of 4 operations (range, 1–4), as was reported in 3 studies (42/103 patients).

Four studies (60/109 patients) reported the decrease in IAP after surgical decompression. The median IAP decreased from 33 (range, 30–36 mm Hg) to 18 mm Hg (range, 15–20 mm Hg). In these studies, elevated IAP was associated with concomitant organ failure. Three studies reported the effect of decompression on organ failure.[3,9,26] In 1 study, the authors reported a significant difference in improvement of physiologic parameters (ie, mean arterial pressure, heart rate, arterial oxygenation, and urine output) within 24 hours after decompression.[9] Both other studies[3,26] used different methods of reporting organ failure (ie, the percentage of patients with organ failure, Multiple Organ Dysfunction Score [MODS] or Sequential Organ Failure Assessment [SOFA] score) before and after decompression. Therefore, comparison of results was not possible.

The overall mortality rate (including patients without ACS) was 26% (69/271 patients), with a range of 18% to 46% per study. The overall mortality rate in patients with acute pancreatitis and ACS was 49% (50/103 patients), with a range of 25% to 83% per study. Mortality in the ACS subgroup is shown in a forest plot (Fig. 2). There was substantial heterogeneity for mortality (I^2 = 57%, P = 0.03). The mortality in patients with acute pancreatitis without ACS was 11% (19/168 patients).

All studies (103 patients) reported the number of complications; a total of 158 complications were described. Two studies reported pancreatic infection as complication in 24 (52%) of the 46 patients with ACS. Three studies reported on septic shock, which occurred in 22 (47%) of the 47 patients. Enterocutaneous and pancreatic fistulas were reported in 3 studies and occurred respectively in 12 (23%) and 3 (6%) of the 52 patients with ACS. Two studies reported on incisional hernia, which occurred in 12 (46%) of the 26 patients. The first study applied temporary abdominal closure after decompressive laparotomy in all patients followed by delayed abdominal closure (11/16 patients) or split-thickness skin graft (5/16 patients).[25] The

TABLE 4. Patient Characteristics of the Included Studies

Study	No. Patients With ACS	M/F (%)	Mean Age	Etiology	Mean APACHE II Score	Mean Glasgow-Imrie Score on Admission	Mean CRP	Ranson Score
Bezmarevic et al[24]	6	23/6 (79/21)*	55*	A: 6 B: 13 Hy: 5 Ia: 1 O: 4*	16*	nr	180*	nr
Chen et al[9]	20	23/21 (52/48)†	63†	A: 5 B: 26 Hy: 7 O: 6†	16†	nr	nr	4†
Davis et al[25]	16	16/0 (100/0)	56	A: 7 B: 7 Ia: 0 O: 2	23	10	nr	6
De Waele et al[3]	4	15/6 (71/29)‡	53‡	A: 8 B: 7 Hy: 3 O: 3‡	21‡	nr	34‡	7‡
Leppäniemi et al[26]	10	9/1 (90/10)	46	A: 9 Ia: 1	nr	nr	nr	nr
Mentula et al[7]	26	23/3 (88/12)	42	A: 21 Ia: 3 O: 2	nr	nr	nr	nr
Tao et al[27]	21	14/7 (67/34)	41	nr	19	nr	nr	nr

*No data available on patients with ACS only, data reported of whole cohort of patients with acute pancreatitis.
†No data available on patients with ACS only, data reported for patients with IAP >12 mm Hg.
‡No data available on patients with ACS only, data reported for patients with IAP >15 mm Hg.
A indicates alcoholic; B, biliary; Hy, hyperlipidemia; Ia, iatrogeneous; nr, not reported; O, other; SAP, severe acute pancreatitis.

other study performed a subcutaneous linea alba fasciotomy in all patients; 4 patients required additional laparostomy.[26]

The mean total hospital stay for patients with ACS was 76 days; this was reported in 3 studies (47/109 patients). The total mean ICU stay was 23 days.

DISCUSSION

This systematic review shows that ACS in acute pancreatitis is associated with a mortality rate of 49%. Surgical decompression lowers the IAP considerably. However, it is not possible to relate this decrease in IAP to clinical outcome from the available literature. It therefore remains unknown when and if invasive intervention should be performed and which method (ie, percutaneous catheter drainage or various surgical decompression techniques) is most effective in clinical outcomes.

The 2013 WSACS guidelines proposed clear definitions for ACS (Table 1).[2] Of the 7 studies in the current review, 5 reported the definitions used for ACS; 4 of them used the WSACS definition, that is, sustained IAP of more than 20 mm Hg associated with new organ failure. Five studies reported on IAP measurements; all used the transvesical method as advised in the same guidelines.[2]

The results of this study should be interpreted, taking into account several shortcomings. The methodological quality of most of the included studies was moderate to low, which reflects a high risk of bias that may have affected the outcome. Patient populations were heterogeneous, and patient characteristics and outcomes were not reported in a uniform manner. Different scoring systems were used to report the severity of the disease (eg, APACHE II scores, Ranson scores, Glasgow-Imrie scores, or C-reactive protein (CRP)) and organ failure (eg, SOFA, MODS, single organ failure, multiple organ failure), which made adequate comparison impossible. Furthermore, the number of patients with ACS in the different cohorts was small, with a range of 4 to 26. The incidence of ACS also varied greatly from 9% to 36% between the different cohorts. A mean incidence of ACS in acute pancreatitis of 22% is very high and probably overestimated. This could be a result of the chosen, for this question not specific, inclusion and exclusion criteria. Notably, the reported incidence of ACS in a recent prospective observational cohort study on the outcome of 639 patients with necrotizing pancreatitis who did not meet the eligibility criteria for the current study was as low as 2% (15/639 patients).[28] Conversely, the reported incidences of ACS and associated mortality in patients with severe

Pancreatic Necrosis, n %	Patients Admitted in ICU (%)	Organ Failure, n (%)	Mean IAP (24 h of Admission), mm Hg	Time of Admission After Disease Onset, d	Mean Time SAP to ACS, d	IAH in Whole Cohort, n (%)	ACS in Whole Cohort, n (%)	Mean Diagnosis ACS to First Intervention, d
25 (86)*	nr	Single, 5 (17) Multiple, 24 (83)*	15*	1*	8*	27 (53)	6 (12)*	1*
nr	20 (100)	MODS, 18	37	nr	1	44 (60)	20 (27)	1
nr	16 (100)	SOFA, 9	29	nr	nr	nr	16 (36)	1
20 (95)‡	21 (100)‡	Pulmonary, 20 (95); cardiovascular, 19 (91); renal, 18 (86)‡	37	nr	nr	21 (48)‡	4 (9)	nr (6 within 2 d; overall range, 1–17)
nr	10 (100)	SOFA, 12	31	nr	nr	10 (100)	10 (100)	nr
nr	26 (100)	SOFA, 12	31	2	nr	26 (100)	26 (100)	1
nr	nr	Pulmonary, 21 (100); cardiovascular, 21 (100); renal, 21 (100)	32	nr	28	21 (100)	21 (100)	1 (9 within 5 h, 6 within 5–10 h, 1 after 14 h, 1 after 19 h, and 1 after 22 h)

burn and trauma are comparable with the results in the pooled data of this systematic review.[29–33]

Many patients with overt ACS in whom nonoperative methods have failed undergo surgical decompression. Given the morbidity of open abdominal decompression, noninvasive means of reducing IAP are an appealing alternative. These include sedation, neuromuscular blockade, nasogastric decompression, and correction of a positive cumulative fluid balance. With respect to the latter, aggressive fluid resuscitation is hypothesized to be 1 of the possible causes of secondary ACS in acute pancreatitis.[10] Mao et al[10] performed a randomized controlled trial comparing rapid fluid expansion (10–15 mL/kg per hour infusion rate) and controlled fluid expansion (5–10 mL/kg per hour infusion rate) in 76 patients with severe acute pancreatitis. There was a significant reduction in the incidence of ACS in the controlled fluid group (33% vs 72%; $P < 0.05$). Mortality rate was also remarkably lower as compared with the rapid fluid group (70% vs 90%; $P < 0.05$).[10] Partly on this basis, the new International Association of Pancreatology (IAP)/American Pancreatic Association (APA) consensus guidelines on acute pancreatitis advise goal-directed fluid therapy with 5 to 10 mL/kg per hour.

In addition to noninvasive treatment strategies, another promising alternative for surgical decompression is percutaneous catheter drainage. The 2013 WSACS guidelines suggest percutaneous catheter drainage as first step of invasive treatment in patients with intraperitoneal fluid because this may alleviate the need for decompressive laparotomy.[2] In current study, only 11% of patients with ACS underwent percutaneous drainage as first intervention. Complications and mortality were unfortunately not reported for this subgroup, and more than half of the patients needed additional decompressive laparotomy after initial percutaneous drainage. Clearly, more data on percutaneous drainage in ACS are needed. A point of concern is the risk of infecting sterile necrotizing pancreatitis by drainage. It would seem preferred to drain intraperitoneal fluid (ie, ascites) rather than retroperitoneal fluid, but further studies should address this issue. Our systematic search for ongoing randomized controlled trials identified 1 study. The DECOMPRESS trial[23] has now randomized 78 (78%) of the 100 patients with severe acute pancreatitis and ACS to either percutaneous drainage or decompressive laparotomy (personal communication with principal investigator, Dejan V. Radenkovic, dejanr@sbb.rs, May 22, 2013).

TABLE 5. Weighted Means for Baseline and Outcome

	No. Studies	No. Patients	Mean
Follow-up, mo	6	93	39
Methodological quality	7	103	4.4
Sex (M/F), %	7	167	74/26
Age, y	7	167	53
Etiology (B, A, Ia, Hy, O), %	6	146	A, 38; B, 36; Hy, 10; Ia, 3; O, 13
APACHE II	5	131	18
CRP	2	50	119
Ranson	3	81	5
Glasgow-Imrie	1	16	10
ICU admission, %	5	93	100
IAP, mm Hg	7	126	28
IAH, %	6	226	66
ACS, %	7	271	38
Mean time to admission from onset symptoms, d	2	55	1
Time SAP to ACS, d	3	70	12
Mean diagnosis of ACS to first intervention, d	5	112	<1
No. patients undergoing interventions, %	7	103	100
Decompressive laparotomy as first intervention, %	7	103	74
Percutaneous intervention as first intervention, %	7	103	11
No operation for ACS, %	7	103	16
Midline laparotomy, %	7	103	67
Bilateral subcostal laparotomy, %	7	103	1
Subcutaneous linea alba fasciotomy, %	7	103	17
Decrease of IAP after surgical decompression mm Hg	4	60	15
Median no. reoperations per patient	3	42	3
Total hospital stay, d	3	47	76
Total ICU stay, d	2	31	23
Mortality in the ACS group, %	7	103	49
Mortality in patients with acute pancreatitis without ACS, %	4	168	11
Mortality in whole cohort, %	7	271	26
Complications (total in all cohorts)	7	103	158
Pancreatic infection, %	2	46	52
Septic shock, %	3	47	47
MODS, %	3	34	68
Enterocutaneous fistula, %	3	52	23
Pancreatic fistulas, %	3	52	6
Intraabdominal infection, %	3	57	39
Incisional hernia, %	2	26	46

A indicates alcoholic; B, biliary; Hy, hyperlipidemia; Ia, iatrogeneous; O, other SAP, severe acute pancreatitis.

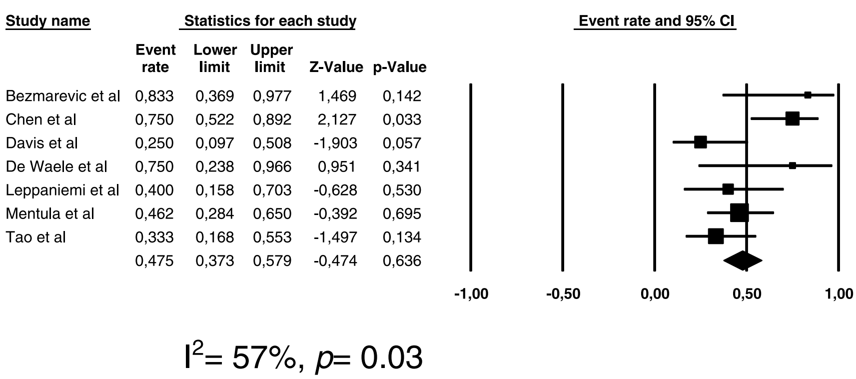

FIGURE 2. Forest plot of included studies analyzing mortality of ACS.

TABLE 6. Outcome of Patients With ACS

Study	ACS, %	No. Patients Undergoing Intervention	Decompressive Laparotomy as First Intervention, n (%)	Percutaneous Drainage as First Intervention, n (%)	No Operation for ACS, n (%)	Midline Laparotomy, n (%)	Transverse Bilateral Subcostal Laparotomy, n (%)	Subcutaneous Linea Alba Fasciotomy, n (%)	Decrease of IAP After Surgical Decompression, mm Hg	Median No. Reoperations per Patient	Total Hospital Stay, d	Total ICU Stay, d
Bezmarevic et al[24]	6 (12)	6 (100)	2 (33)	3 (50)	1 (17)	5 (83)	0	0	nr	1	nr	nr
Chen et al[9]	20 (27)	20 (100)	0	8 (40)	12 (60)	5 (25)	0	0	18	nr	nr	nr
Davis et al[25]	16 (36)	16 (100)	16 (100)	0	0	16 (100)	0	0	nr	nr	146	nr
De Waele et al[3]	4 (9)	4 (100)	4 (100)	0	0	4 (100)	0	0	19	nr	42*	21*
Leppäniemi et al[26]	10 (100)	10 (100)	10 (100)	0	0	0	0	10 (100)	10	1	35	26
Mentula et al[7]	26 (100)	26 (100)	26 (100)	0	0	18 (69)	1 (4)	7 (27)	15	4	nr	nr
Tao et al[27]	21 (100)	21 (100)	18 (86)	0	3 (14)	18 (86)	0	0	nr	nr	nr	nr

Study	Mortality in the ACS Group, n (%)	Mortality in Patients With Acute Pancreatitis Without ACS, n (%)	Mortality in Whole Cohort, n (%)	Complications	Pancreatic Infection	Septic Shock	MODS	Enterocutaneous Fistula	Pancreatic Fistulas	Intraabdominal Infection	Incisional Hernia	Other
Bezmarevic et al[24]	5 (83)	4 (9)	9 (18)	1	nr	1	nr	nr	nr	nr	nr	nr
Chen et al[9]	15 (75)	2 (4)	17 (23)	44	12	14	18	nr	nr	nr	nr	nr
Davis et al[25]	4 (25)	7 (24)	11 (24)	31	nr	nr	nr	7	3	nr	8	3 wound dehiscences 10 wound infections
De Waele et al[3]	3 (75)	6 (15)	9 (33)	3	nr	nr	1	nr	nr	nr	nr	2 hemorrhagic shock
Leppäniemi et al[26]	4 (40)	-	4 (40)	14	nr	nr	4	2	0	2	4	2 postoperative bleeding
Mentula et al[7]	12 (46)	-	12 (46)	35	12	nr	nr	3	0	19	nr	1 biliary fistula
Tao et al[27]	7 (33)	-	7 (33)	30	nr	7	nr	nr	nr	1	nr	11 hemorrhage of upper digestive tract 4 pancreatic encephalopathy 5 abdominal abscess plus obstruction 1 gastric perforation 1 colon perforation

All data are reported as mean.

*No data available on patients with ACS only, data reported for patients with IAP >15 mm Hg.

nr indicates not reported.

The effects of surgical decompression were poorly reported in the included studies. Only 4 studies described its effect on lowering IAP, and 3 to 6 studies reported its effect on organ function and complications, respectively. Although IAP was consistently lower after decompression, mortality remains considerable. This adds to the question whether invasive intervention for ACS truly improves patient outcomes. Severity of acute pancreatitis may be far more important for the prognosis than solely the presence of ACS. These questions cannot be answered with current available data. In addition, even more detailed information is required, such as whether the degree of increase in IAP per hour affects the need for intervention and which cutoff for IAP should ideally be used if intervention truly is beneficial.

With regard to the technique of surgical decompression, full-thickness midline laparotomy was performed in most patients. In 2 studies, a subcutaneous linea alba fasciotomy was performed and 1 patient underwent full-thickness transverse bilateral subcostal laparotomy. We were unable to compare the different surgical procedures used because most studies did not differentiated complications and mortality between procedures and some patients underwent multiple interventions. Avoiding full-thickness incision in the midline including skin, subcutaneous tissue, and fascia might be better to prevent fistula formation and incisional hernia. Fascial release through separate lateral skin incisions is an option to achieve decompression, avoiding complications of an open abdomen.

Overall mortality in the ACS group was 49% and almost 5 times as high as the mortality rate in patients with acute pancreatitis without ACS. Seven studies reported the total number of complications. However, the exact nature of these complications was often not reported, as well as the number of patients with 1 or more complications. Furthermore, besides mortality, only 3 studies reported important outcomes as enterocutaneous fistula, pancreatic fistula, and incisional hernia.

This systematic review has identified considerable limitations of the published literature on ACS in acute pancreatitis. Well-designed prospective and preferably randomized studies are required to answer the many remaining questions and establish standards for treatment of this life-threatening complication. These studies should use established definitions of IAH and ACS as well as validated techniques of measuring IAP.

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