Prevalence and Mortality of Abdominal Compartment Syndrome in Severely Injured Patients; a Systematic Review and Meta-Analysis

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Abstract

Background: Abdominal Compartment Syndrome (ACS) in severely injured patients is associated with high morbidity and mortality. Many efforts have been made to improve outcome of patients with ACS. A treatment algorithm for ACS patients was introduced on January 1, 2005 by the World Society of the Abdominal Compartment Syndrome (WSACS). The aim of this study was to estimate prevalence and mortality of ACS among severely injured patients, and to compare the prevalence and mortality before and after January 1, 2005 using a systematic literature review and meta-analysis.

Method: Databases of Embase, Medline (OvidSP), Web-of-science, CINAHL, CENTRAL, PubMed publisher and Google Scholar were searched for terms related to severely injured patients and ACS. Original studies reporting ACS in trauma patients were considered eligible. Data on study design, population, definitions, and outcomes were extracted. Estimates of overall prevalence and mortality of ACS among severely injured patients were calculated using inversed variance weighting assuming a random effects model. Tests for heterogeneity were applied.

Results: A total of 81 publications were included. The overall prevalence of ACS among severely injured patients was 4.5% (95% Confidence Interval, CI, 3.5-5.7%; N= 33,455). Prevalence among severely injured patients admitted to the ICU was estimated 1.2% (95% CI: 0.8-1.7%; N= 11,279), and 3.0% (95% CI: 1.7-4.7%; N= 5,557) among patients with visceral injuries and 7.8% (95% CI: 3.9-12.9%; N= 4,687) among patients who underwent trauma laparotomy. The overall mortality rate among severely injured patients with ACS was 48.3% (95% CI, 41.5-55.2%; N= 967). No significant change was found in estimated prevalence and mortality of ACS among severely injured patients before and after January 1, 2015.

Conclusion: The pooled prevalence of ACS among severely injured patients is 4.5%. The pooled mortality rate of these patients is 48.3%. Modern trauma resuscitation and introduction of evidence-based treatment algorithms have not resulted in a decrease of reported prevalence and mortality of ACS among severely injured patients.

Keywords: Intra-abdominal pressure, intra-abdominal hypertension, abdominal compartment syndrome, prevalence, mortality

Level of evidence: Level III

Study type: Systematic Review and Meta-Analysis

Introduction

Abdominal compartment syndrome (ACS) is a well described, serious complication in severely injured patients. It is a syndrome of pathologically increased intra-abdominal pressure (IAP), normally as a result of intra-abdominal hemorrhage, use of large volumes of resuscitation fluid, or abdominal surgery. The diagnosis of ACS is confirmed if IAP exceeds 20 mmHg (*i.e.*, high grade intra-abdominal hypertension; IAH) in combination with splanchnic hypoperfusion and subsequent organ dysfunction.

ACS was initially recognized as a typical complication among trauma populations, although it is also described in many other critically ill patient groups. Even though this complication is relatively infrequently seen, it should not be missed because of the presumed high risk of associated morbidity and mortality [1-4].

Many efforts have been made in to improve the outcome of severely injured patients over passed decades. Several developments in trauma care may have improved the outcome of ACS patients directly or indirectly. For example, the introduction of damage control resuscitation has decreased the need for large fluid resuscitation volumes [5]. The shift from crystalloids to the more liberal use of plasma and colloid or hyperosmolar solutions might have theoretically decreased the risk of extravasation of administered fluids [6]. More deliberated use of damage control surgery may have decreased the risk of iatrogenic injury or additional and unnecessary inflammatory responses [7]. Lastly, vacuum assisted temporary abdominal closure devices (TAC) have made open abdomen treatment easier and decreased the risk for secondary intra-abdominal fluid collection, edema formation, and closure problems [8].

The World Society of the Abdominal Compartment Syndrome (WSACS) critically reviewed literature regarding these developments and subsequently introduced the Consensus

Statements and Recommendations using the GRADE methodology. These statements serve as guidelines for the treatment of patients at risk for IAH/ACS and were first implemented on January 1, 2005 (but published in 2006) [9]. An updated version of these guidelines provide physicians with easy-to-use treatment algorithms [10]. The application of these algorithms have resulted in a decrease of ACS mortality in a mixed population of trauma and non-trauma patients [11].

It is however unclear to what extent these developments have affected the ACS prevalence and ACS mortality among severely injured patients. The primary aim of this study was to determine the prevalence and mortality rate of ACS among severely injured patients, as well as in three subgroups of 1) severely injured patients admitted to the Intensive Care Unit (ICU), 2) patients who have sustained visceral injury, and 3) patients who have undergone trauma laparotomy, based upon available literature. The secondary aim was to compare prevalence and mortality rates of studies performed before January 1, 2005 with those performed after that date.

Methods

This systematic literature review was conducted and reported according to the standards set out in Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [12]

Ethics statement

The current study used secondary data, extracted from readily available literature; therefore, obtaining research ethics approval was not necessary.

Search Strategy

Databases of Embase, Medline (OvidSP), Web-of-science, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Central Register of Controlled Trials (CENTRAL), PubMed publisher and Google Scholar were searched from database inception until February 15, 2015. Searched items consisted of terms related to injury and terms related to abdominal compartment syndrome. Reference lists of review articles and eligible studies were reviewed for additional studies that may have been missed (Supplemental Digital Content; SDC 1**)**.

Manuscript Selection

Titles and abstracts were screened independently by two reviewers (SGS and RAV) for presence of trauma populations. Inconsistencies were resolved by discussion and consensus. Studies were included if they met the following inclusion criteria: 1) design: original reports with primary data; 2) population: presence of injured patients, and 3) outcome: description of ACS prevalence or ACS mortality numbers or data from which prevalence or mortality rates among injured patients could be calculated. No language criterion was used. Studies were

excluded if no full text version was available after contacting corresponding authors. Also, studies restricted to thermally injured patients were excluded, as a systematic review on prevalence and outcome of IAH and ACS among severely burned patients is already available [13]. No specific definitions for injured patients or ACS were used as eligibility criterion.

Scientific Level of Evidence

Study classification according to Mahid *et al.* and the prospective- and retrospective nature of the studies were collected in order to assess the type and level of evidence of publications; randomized controlled trials (RCTs), cohort studies, and case series were found to be eligible [14]. The patient groups of RCTs were taken together, the pooled study population was considered one cohort over which prevalence or mortality rate was calculated.

Data Extraction

Data extraction was done independently in duplicate by three reviewers (SGS, OJFVW and AVVB) using a standardized data sheet. Discordance was resolved by the reviewers rechecking their extracted data until data sheets corresponded. The following data were extracted for each publication: name of first author, publication year, years the inclusion period started and ended, population size (N), type of population, age of population, mean or median injury severity score (ISS), definition used for ACS, number of ACS patients (or ACS rate), and mortality rate of ACS patients. Publications using the same patient database in overlapping periods were identified. Only data from 1) the largest or 2) most recent cohorts were used.

Data synthesis and statistical analysis

ACS prevalence and mortality rates were computed for each study; they were transformed using a double arcsine transformation in order to ensure normal distribution [15]. Next, the transformed rates and 95% confidence intervals were transformed back to prevalence and mortality rate estimates. Forest plots were constructed with 95% confidence interval for all studies to show the variation in ACS prevalence and mortality in severely injured patients across the included studies.

The Cochrane Chi-squared (χ^2) Q-test was applied in order to test for heterogeneity (significance set at $p < 0.10$), and the I^2 statistic was calculated in order to quantify the degree of between-study heterogeneity. This defines the variability percentage in effect estimates that is due to heterogeneity rather than to chance [16, 17]. An I^2 statistic greater than 40% was considered to represent significant heterogeneity.

Data were pooled using a random-effects model for binomial data (DerSimonian–Laird) [18]. A random-effects model was planned a priori, due to the degree of anticipated heterogeneity among the eligible studies. If significant heterogeneity was present, subgroup analyses were planned for 'severely injured patients admitted on the ICU', 'patients with visceral injuries' and 'patients who had undergone emergent trauma laparotomy'.

For the secondary analysis the populations were divided into comparable groups with a median inclusion year before and after January 1, 2005. This date was used as cutoff, since the WSACS guideline was first implemented on that date [11]. If the inclusion period was not specified, the year of publication was used as cutoff date. Differences in ACS prevalence and mortality rates between the two time periods were tested using a unpaired Student's *t* test. A p-value below 0.05 was considered statistically significant.

Analyses was performed using MetaXL software (Version 2.2; Epigear International Pty Ltd, Australia; 2011-2015). Student's *t* test was calculated using the GraphPad QuickCalcs web site (http://graphpad.com/quickcalcs/ttest1/?Format=SEM).

Results

Trial identification

The search yielded 5,899 publications. After eliminating duplicates, 3,755 publications remained. These were reviewed for inclusion and exclusion criteria, and reference lists of reviews and eligible studies were examined for additional publications. A total of 81 publications was included in this analysis, including three randomized controlled trials, 13 prospective cohort studies, 40 retrospective cohort studies, and 25 case series (Figure 1). Extracted data of included publications are listed in SDC 2. The search identified no systematic reviews or meta-analysis regarding prevalence and mortality rate of ACS among injured patients. Only one previously published literature review listed prevalence and outcome of ACS among trauma patients in 2009. This study, however, did not describe a systematic search method [19]. One publication reported sufficient data to calculate annual prevalence between 2002 and 2007. The annual prevalences of this publication were pooled in a group before January 1, 2005 and a group after that date. These sub-groups were separately included to the different pooled populations [11].

Prevalence of ACS in severely injured patients

The pooled prevalence of ACS for 33,455 severely injured patients in 61 publications was 4.5% (95% Confidence Interval, CI: 3.5-5.7%) with large heterogeneity (I^2 = 94.5%, 95% CI 93.6-95.4%) (Figure 2). Prevalence of studies conducted before January 1, 2005 (4.5%; 95% CI 3.3-5.9%; 20,891 patients; 41 publications) was not statistically significantly different from that conducted after that date (4.3%; 95% CI 2.6-6.4%; 12,564 patients; 20 publications; P= 0.823; Table 1).

Given the large heterogeneity, subgroup analyses were performed for. Pooled prevalence for these subpopulations were 1.2% (95% CI: 0.8-1.7%; 11,279 patients; 9 publications; I^2: 75.1%, 95% CI: 51.8-87.1%; Figure 3A) for severely injured patients admitted to the ICU, 3.0% (95% CI: 1.7%-4.7%; 5,557 patients; 19 publications; I^2: 87.1%, 95% CI: 81.2-91.1%; Figure 3B) for patients who have sustained visceral injuries and 7.8% (95% CI: 3.9%-12.%; 4,687 patients; 14 publications; I^2: 96.6%, 95% CI: 93.6.8-95.4%; Figure 3C) among severely injured patients who underwent trauma laparotomy. The pooled prevalence of these subgroups before January 1, 2005 seemed not statistically significantly different from that conducted after that date, since 95% CI's overlapped considerably. P-values were not calculated since 95% CI's were too skewed.

Mortality of severely injured patients with ACS

The pooled mortality for 967 severely injured patients with ACS in 42 publications was 48.3% (95% CI: 41.5-55.2%) with large heterogeneity (I^2 = 75.4%, 95% CI: 66.9-81.7%). Pooled mortality was 47.3% (95% CI: 40.8-53.9%; 668 patients; 32 publications) before January 1, 2005 and 51.7% (95% CI: 32.3-70.8%; 299 patients; 10 publications) after January 1, 2005 (p= 0.598; Table 2).

Discussion

Even though many efforts have been made the last decade to improve the outcome of ACS among severely injured patients, no significant effect on prevalence and mortality could be identified. This was unexpected, especially since the contribution of improved modern trauma care and the introduction of the Consensus Statements and Recommendations by the WSACS seem obvious steps forward in trauma care as a whole and in evidence-based treatment of ACS patients.

An obvious explanation for not finding lower prevalence and mortality rates since 2005 is the lack of adequate data. On the other hand, if prevalence and mortality rates indeed remained stable over time, our findings might indicate that modern trauma resuscitation or the WSACS guidelines are not widely known or applied in published studies. Assuming that the evidence-based treatment algorithm is effective, it is notable that its use is not frequently described in included publications. Even definitions of ACS are still not uniformly applied in modern literature [20]. A large prospective multicenter cohort study would give more clarity on the subject. Especially the use of specific and relevant inclusion criteria and uniform definitions would improve the quality of estimated prevalence and mortality of ACS among severely injured patients.

The current systematic review and meta-analysis has certain limitations due to the inherent biases of the included studies. The findings should thus be interpreted with caution. The studies had different study designs (*i.e.*, RCT, longitudinal cohort study, or case series), diverse populations, and used different definitions of ACS. This partly explains the large between-study heterogeneity, and again outlines the need for more rigorous and uniform

definitions in future studies. Despite these limitation, the strength of the current study is its robust methodology. It pooled data from 81 studies with a large overall sample size. In an attempt to minimize bias, multiple authors independently applied the eligibility criteria to the titles, abstracts, and the full-text of the articles, and subsequently collected data.

In conclusion, the pooled prevalence of ACS among severely injured patients is 4.5%. The pooled mortality of these patients is 48.3%. Even though many efforts have been made in the last decade to improve the outcome of ACS among severely injured patients, it has not yet resulted in a decrease of reported prevalence and mortality rate among these patients.

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Author contribution statement

Each author contributed significantly to the design, data acquisition, analysis and interpretation of data, drafting or critical revision of this manuscript and each author provided final approval of the submitted manuscript. The authors contributed in the following:

SGS:	Design, data acquisition, analysis and interpretation, drafting and critical revision of the manuscript
EMMVL:	Design, data analysis and interpretation and critical revision of the manuscript
OJFVW:	Data acquisition, data interpretation and critical revision of the manuscript
MHJV:	Data interpretation and critical revision the manuscript

Figure 1 – Flowchart

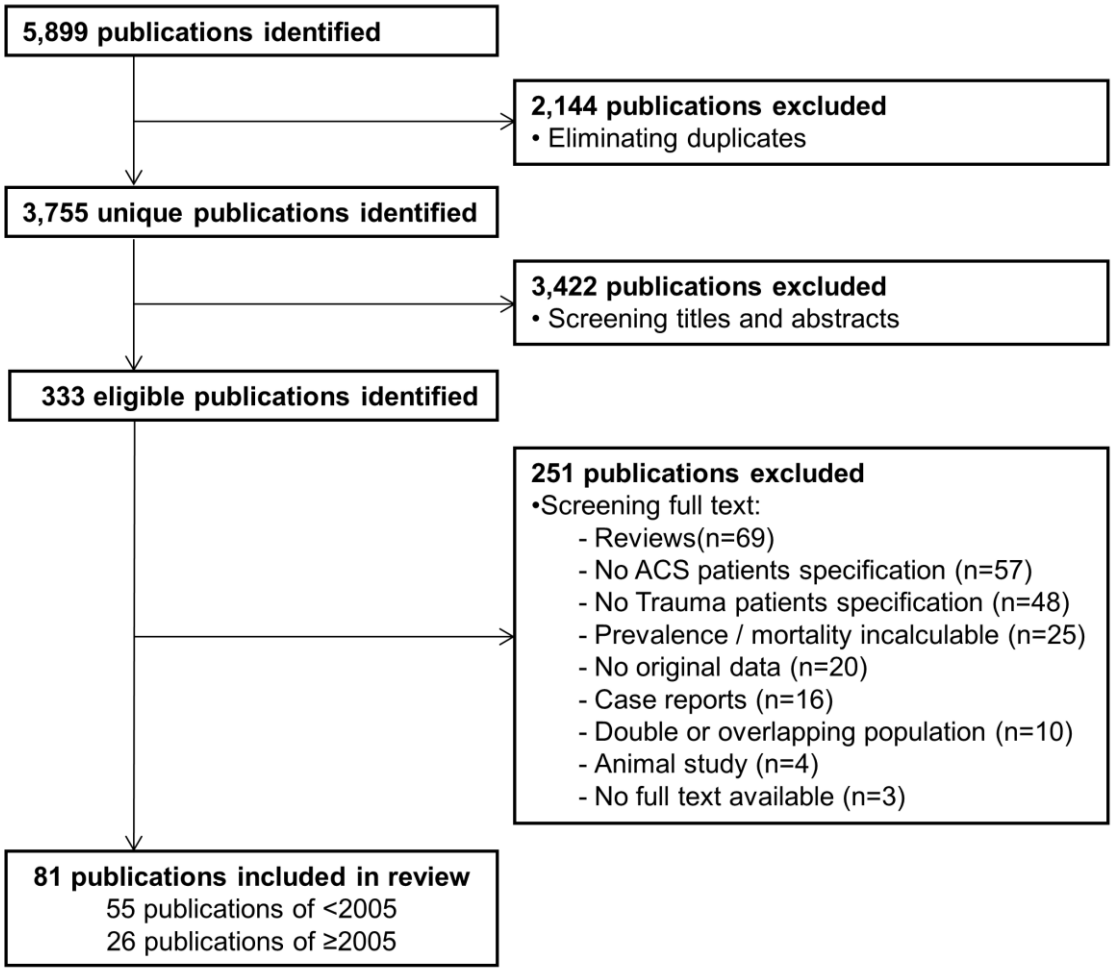


Table 1 – Pooled prevalence of abdominal compartment syndrome in severely injured patients before and after January 1, 2005

	Population (N)[#]	Pooled prevalence	95% CI	P-value
Overall	33,455	4.5%	3.5-5.6%	
< 2005	19,890	4.6%	3.3-6.0%	0.795[*]
≥ 2005	13,565	4.3%	2.7-6.2%	
ICU patients	11,279	1.2%	0.8-1.7%	
< 2005	6,904	1.1%	0.7-1.8%	N.D.[*]
≥ 2005	4,375	1.1%	0.1-2.9%	
Visceral injuries	5,557	3.0%	1.7-4.7%	
< 2005	3,059	2.9%	1.6-4.6%	N.D.[*]
≥ 2005	2,498	3.1%	0.1-9.1%	
Trauma laparotomy	4,867	7.8%	3.9-12.9%	
< 2005	3,850	8.1%	3.5-14.2%	N.D.[*]
≥ 2005	837	6.4%	0.0-20.0%	

ACS, Abdominal Compartment Syndrome; ICU, Intensive Care Unit; N.D., Not Determined, 95% CI, 95% Confidence Interval.

Data were pooled using a random-effects model for binomial data.

[#]Total population in which the pooled prevalence of ACS was calculated.

[*]Differences between the pooled prevalence < 2005 and ≥ 2005 were tested using an unpaired *t* test. When 95% CI's were too skewed, no p-value was calculated. All differences seem statistically insignificant since 95% CI's overlap considerably.

Table 2 – Pooled mortality rate of abdominal compartment syndrome in severely injured patients before and after January 1, 2005

	Population (N)[#]	Pooled mortality	95% CI	P-value
Overall	967	48.3%	41.5-55.2%	
< 2005	668	47.3%	40.8-53.9%	0.598[*]
≥ 2005	299	51.7%	32.3-70.8%	

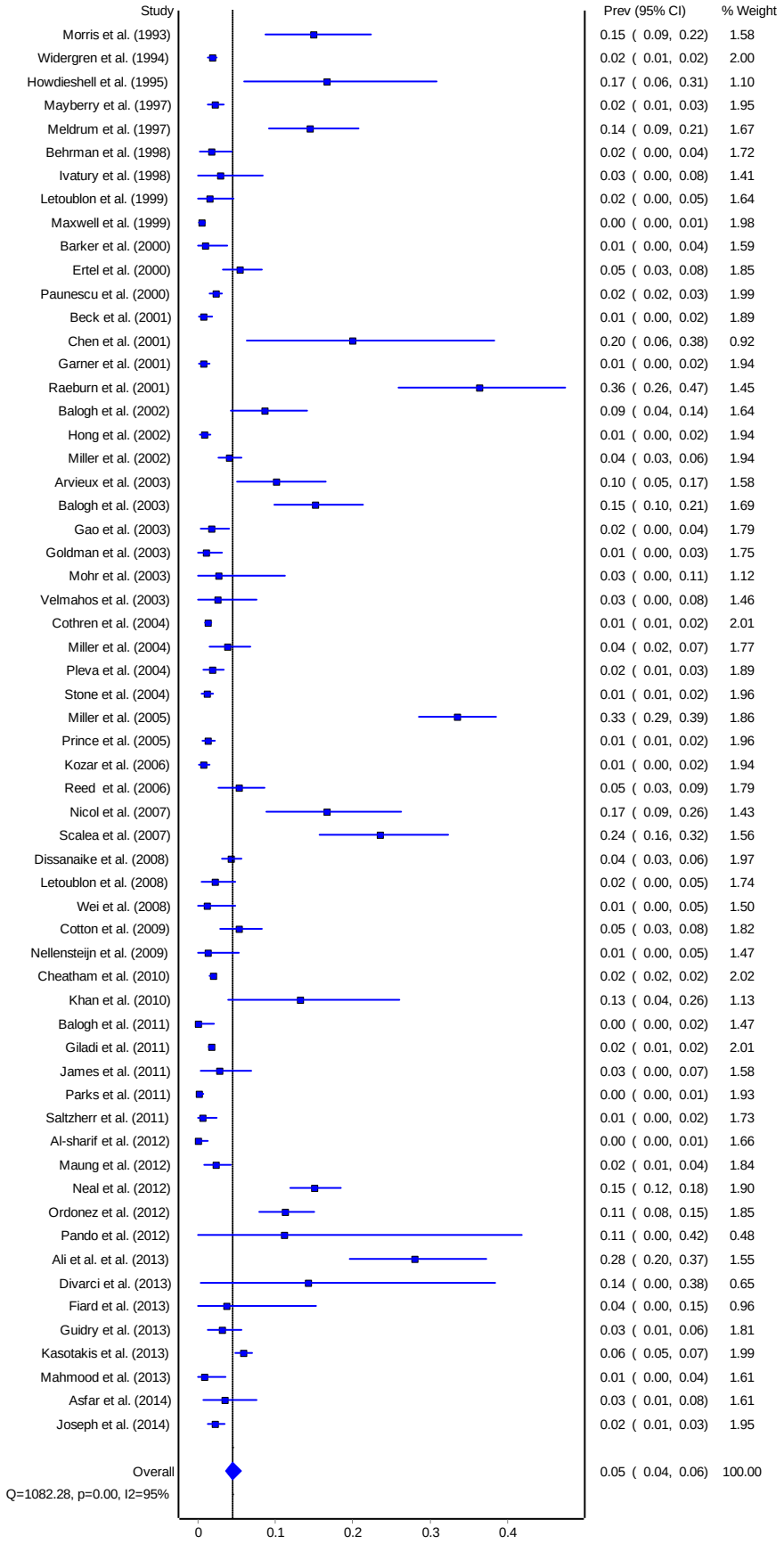
95% CI, 95% Confidence Interval

Pooled mortality rate was calculated using inverse variance weighting and assuming a random effects model. Double arcsine transformation according to Freeman-Tukey was applied.

[#]Total population in which the pooled prevalence of ACS was calculated.

[*]Differences between pooled prevalence and mortality, < 2005 and ≥ 2005 were tested using an unpaired *t* test.

Figure 2 – Forest plot of overall prevalence of ACS among severely injured patients



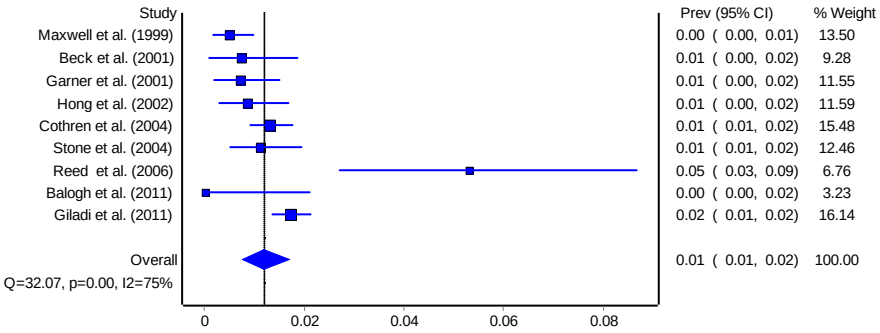
Legend – Figure 2

I2, I^2-statistic for study heterogeneity; Prev, Prevalence; Q, Cochrans Q-statistic for study heterogeneity, 95% CI, 95% Confidence Interval

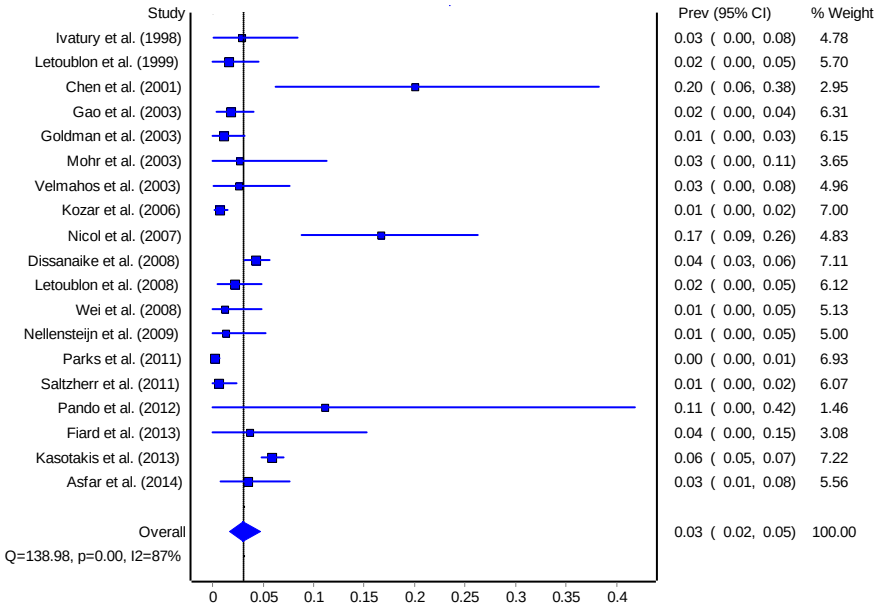
Studies are listen based upon publication year on the y-axis on the left hand side. Prevalence is shown on the x-axis as fraction. The individual study prevalence and corresponding 95% Confidence Intervals and study weight as used in the pooled analysis are listen on the y-axis on the right hand side.

Figure 3A – Forest plot of prevalence of A) severely injured patients admitted to the ICU, B) patients with visceral injuries, and C) patients who had undergone trauma laparotomy

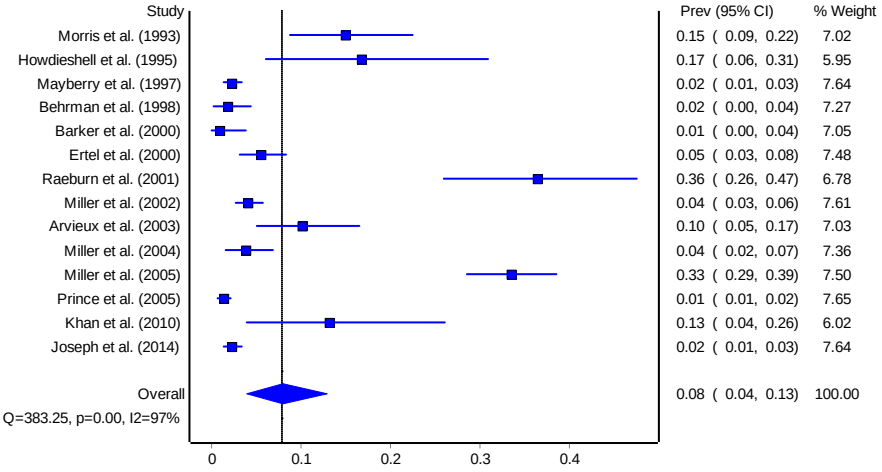
A) Severely injured patients admitted to the ICU



B) Patients with visceral injuries



C) Patients who had undergone trauma laparotomy

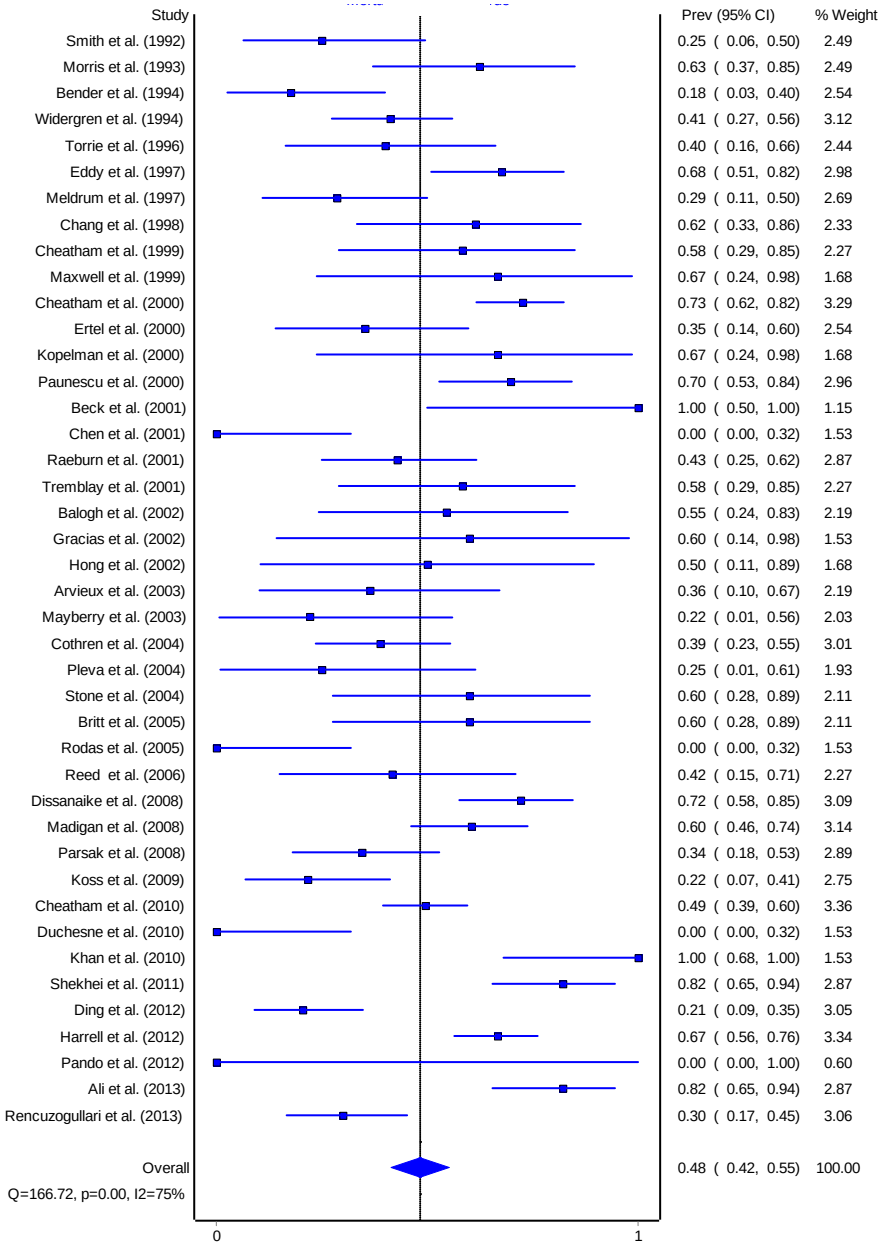


Legend – Figure 3

I2, I^2-statistic for study heterogeneity; Prev, Prevalence; Q, Cochrans Q-statistic for study heterogeneity, 95% CI, 95% Confidence Interval

Studies are listen based upon publication year at the y-axis on the left hand side. Prevalence is shown on the x-axis as fraction. The individual study prevalence and corresponding 95% Confidence Intervals and study weight as used in the pooled analysis are listen at the y-axis on the right hand side.

Figure 4 – Forest plot of ACS mortality among severely injured patients



Legend – Figure 4

I2, I^2-statistic for study heterogeneity; Prev, Prevalence of mortality; Q, Cochrans Q-statistic for study heterogeneity, 95% CI, 95% Confidence Interval

Studies are listen based upon publication year on the y-axis at the left hand side. Mortality rate is shown at the x-axis as fraction. The individual study mortality and corresponding 95% Confidence Intervals and study weight as used in the pooled analysis are listen on the y-axis at the right hand side.

SDC 1 – Search strategy

Database	Query	Hits	Unique
Embase	('abdominal compartment syndrome'/exp OR 'intraabdominal hypertension'/exp OR 'abdominal pressure'/exp OR ('compartment syndrome'/exp AND ('abdominal injury'/exp OR 'abdominal disease'/exp OR 'abdomen'/exp)) OR 'abdominal hypertension'/exp OR 'abdominal decompression'/exp OR 'lower body negative pressure'/exp OR (((abdomin* OR intraabdomin*) NEXT/1 (compartment* OR hypertens* OR pressure* OR decompressi*)) OR 'visceral edema' OR 'visceral oedema')) AND (injury/exp OR traumatology/exp OR 'emergency ward'/exp OR 'emergency medicine'/exp OR emergency/exp OR 'emergency surgery'/exp OR 'emergency health service'/exp OR 'emergency treatment'/exp OR (injur* OR wound* OR trauma* OR penetrat* OR emergen*):ab,ti) NOT ([animals]/lim NOT [humans]/lim)	2,808	2,785
Medline (OvidSP)	('abdominal compartment syndrome'/exp OR 'intraabdominal hypertension'/exp OR 'abdominal pressure'/exp OR ('compartment syndrome'/exp AND ('abdominal injury'/exp OR 'abdominal disease'/exp OR 'abdomen'/exp)) OR 'abdominal hypertension'/exp OR 'abdominal decompression'/exp OR 'lower body negative pressure'/exp OR (((abdomin* OR intraabdomin*) NEXT/1 (compartment* OR hypertens* OR pressure* OR decompressi*)) OR 'visceral edema' OR 'visceral oedema')) AND (injury/exp OR traumatology/exp OR 'emergency ward'/exp OR 'emergency medicine'/exp OR emergency/exp OR 'emergency surgery'/exp OR 'emergency health service'/exp OR 'emergency treatment'/exp OR (injur* OR wound* OR trauma* OR penetrat* OR emergen*):ab,ti) NOT ([animals]/lim NOT [humans]/lim)	1,207	245
Web-of-science	TS=(((((abdomin* OR intraabdomin*) NEAR/1 (compartment* OR hypertens* OR pressure* OR decompressi*)) OR "visceral edema" OR "visceral oedema")) AND ((injur* OR wound* OR trauma* OR penetrat* OR emergen*)) NOT ((animal* OR porcine OR swine OR pig OR rat OR mouse OR mice OR rats OR murine OR dog OR dogs OR rabbit* OR horse* OR equin* OR cat OR cats OR cow OR cows OR bovine) NOT (human* OR patient*)))	1,330	569
CINAHL	(MH "Abdominal Compartment Syndrome+" OR (MH "Compartment Syndromes+" AND (MH "Abdominal Injuries+" OR MH abdomen+)) OR (((abdomin* OR intraabdomin*) N1 (compartment* OR hypertens* OR pressure* OR decompressi*)) OR "visceral edema" OR "visceral oedema")) AND (MH "Wounds and Injuries+" OR MH Traumatology+ OR MH "Emergency Medical Services+" OR MH "emergency medicine+" OR MH emergencies+ OR MH "Emergency Treatment (Non-Cinahl)+" OR (injur* OR wound* OR trauma* OR penetrat* OR emergen*)) NOT (MH animals+ NOT MH humans+)	297	79
CENTRAL	((((abdomin* OR intraabdomin*) NEXT/1 (compartment* OR hypertens* OR pressure* OR decompressi*)) OR 'visceral edema' OR 'visceral oedema')) AND ((injur* OR wound* OR trauma* OR penetrat* OR emergen*):ab,ti)	36	1
PubMed publisher	(Intra-Abdominal Hypertension[mh] OR (Compartment Syndromes[mh] AND (Abdominal Injuries[mh] OR abdomen[mh])) OR intraabdominal compartment*[tiab] OR intra abdominal compartment*[tiab] OR intraabdominal hypertens*[tiab] OR intra abdominal hypertens*[tiab] OR intraabdominal pressure*[tiab] OR intra abdominal pressure*[tiab] OR "visceral edema"[tiab] OR "visceral oedema"[tiab]) AND ("Wounds and Injuries"[mh] OR injuries[sh] OR Traumatology[mh] OR Emergency Medical Services[mh] OR emergency medicine[mh] OR emergencies[mh] OR Emergency Treatment[mh] OR (injur*[tiab] OR wound*[tiab] OR trauma*[tiab] OR penetrat*[tiab] OR emergen*[tiab])) NOT (animals[mh] NOT humans[mh]) AND publisher[sb]	12	9
Google scholar	"abdominal|intraabdominal compartment|hypertension|pressure|decompression"|"visceral edema|oedema" injury|injuries|wound|wounds|trauma|penetrating|emergency|emergencies	200[#]	58
Hand search	Reference lists	9	9
Total		5,899	3,755

[#]First 200 hits.

Databases searched on February 15, 2015

SDC 2 – Data overview of included studies on prevalence and mortality of abdominal compartment syndrome in trauma patients

Publication	Study period	LOE	Pro/Retro	N	Population [Type]	Population [Age]*	ISS**	ACS [definition]	ACS [prevalence]	ACS [mortality]
Smith (1992)[21]	1988-1990	5	Retro	16	Laparostomy	32 (19-51)	29 (16-57)	Massive visceral edema	N.S.	4 (25%)
Morris (1993)[22]	1984-1992	3	Retro	107	DCS	32	33	Tense abdomen + OD	16 (15%)	10 (63%)
Bender (1994)[23]	1986-1991	5	Retro	17	ACS	35 (16-58)	34.2 (25-75)	Not able to close abdomen	N.S.	3 (18%)
Widergren (1994)[24]	1987-1936	3	Retro	2,500	ACS	35 (±18)	30 (±12)	Elevated IAP + OD	46 (2%)	19 (41%)
Howdieshell (1995)[25]	1988-1992	3	Retro	36	TL	Range 13-75	30 (13-50)	IAP + renal failure	6 (17%)	N.S.
Torrie (1996)[26]	1988-1993	5	Retro	15	Trauma ACS	N.S.	34 (19-50)	Not able to close abdomen	N.S.	6 (40%)
Eddy (1997)[27]	1984-1996	5	Retro	34	ACS	30 (±12) (16-58)	33 (±11)	Tense abdomen + OD	N.S.	23 (68%)
Mayberry (1997)[28]	1989-1996	3	Retro	805	TL	37 (±17); 38 (±15)	34 (±13); 30 (±14)	Elevated IAP + OD	18 (2%)	N.S.
Meldrum (1997)[29]	1994-1995	3	Pro	145	ISS >15	39 (±9) (17-59)	26 (±6)	IAP >20 mmHg + OF	21 (14%)	6 (28%)
Behrman (1998)[30]	1994-1996	3	Retro	171	TL	30	30 (±7); 21 (±10)	IAP >25 mmHg	3 (2%)	N.S.
Chang (1998)[31]	1995-1996	5	Pro	13	IAH	37 (±20)	27 (±13)	IAP >25 mmHg OD	N.S.	8 (62%)
Ivatury (1998)[32]	1992-1996	3	Retro	70	Penetrating injury	28 (±9)	22 (±9)	IAH + OD	2 (3%)	N.S.
Cheatham (1999)[33]	1997-1998	5	Pro	12	Laparostomy	51 (±16) (18-71)	32 (±12); 39 (±19)	N.S.	N.S.	7 (58%)
Letoublon (1999)[34]	1985-1998	3	Retro	130	Blunt hepatic injury	32 (±14) (7-74)	N.S.	N.S.	2 (2%)	N.S.
Maxwell (1999)[35]	1997-1998	5	Retro	1,216	Trauma ICU	36 (±7) (15-63)	25 (±3)	Laparostomy. no abd. injury	6 (1%)	4 (67%)
Barker (2000)[36]	1992-1999	3	Retro	112	TL	39 (±17) (5-80)	28 (±14) (5-75)	Elevated IAP + OD	1 (1%)	N.S.
Cheatham (2000)[37]	1997-1999	5	Retro	73	ICU and IAH	51 (±19)	33 (±16)	IAP ≥25 mmHg + OD	N.S.	53 (73%)
Ertel (2000)[38]	1991-1998	3	Pro+Retro	311	DCL	38 (±1)	30 (±0.7)	Tense abdomen + OD	17 (6%)	6 (35%)
Kopelman (2000)[39]	N.S.	5	Retro	6	ACS	46 (±6)	17	N.S.	N.S.	4 (67%)
Paunescu (2000)[40]	1992-1999	3	Retro	1,456	Polytrauma	N.S.	N.S.	N.S.	33 (2%)	23 (68%)
Beck (2001)[1]	1994-1999	5	Pro	406	Pediatric ICU	0; 2; 3	N.S.	IAP >15 mmHg + OD	3 (1%)	3 (100%)
Chen (2001)[41]	1998-1999	5	Pro	25	Blunt hepatic injury	30 (±9) (15-54)	20 (±5) (9-41)	IAP >25cmH2O	5 (20%)	0 (0%)
Garner (2001)[42]	1999-2000	3	Retro	698	Trauma ICU	41 (±4.7)	24 (±1.0)	Decompression	5 (1%)	N.S.
Raeburn (2001)[43]	1996-2000	3	Pro	77	DCS	35 (15-77)	29 (±2)	IAP >20 mmHg + OD	28 (36%)	12 (43%)
Tremblay (2001)[44]	1997-2000	5	Retro	12	Laparostomy	36 (±17) (7-81)	24 (±11)	Elevated IAP + OD	N.S.	7 (58%)
Balogh (2002)[45]	1997-2001	3	Retro	128	Shock resuscitation	41 (±5)	28 (±3)	Laparostomy. no abd injury	11 (9%)	6 (55%)
Gracias (2002)[46]	1999-2000	5	Retro	5	Laparostomy	35 (±10)	33 (±19)	IAH + OF	N.S.	3 (60%)
Hong (2002)[47]	1998-1999	3	Pro	706	Trauma ICU	42 (14-90)	18 (1-75)	Decompression	6 (1%)	3 (50%)
Miller (2002)[48]	1996-2011	3	Retro	646	TL	40	32	Decompression	26 (4%)	N.S.
Arvieux (2003)[49]	1990-2001	3	Retro	109	DCS	34 (±16)	32 (±15)	Intestinal edema	11 (10%)	4 (36%)
Balogh (2003)[50]	1999-2002	3	Retro	152	Severe injury	39 (±1); 41 (±2)	27 (±1); 28 (±2)	IAP >25 mmHg + OD	23 (15%)	N.S.
Gao (2003)[51]	1988-2000	3	Retro	225	Hepatic injury	28 (7-73)	27 (4-75)	N.S.	4 (2%)	N.S.
Goldman (2003)[52]	1995-2000	3	Retro	192	Blunt hepatic injury	30 (±9)	25 (±15)	Decompression	2 (1%)	N.S.
Mayberry (2003)[53]	1993-1998	5	Retro	9	Severely injured patient	47 (20-57)	24 (±9)	Decompression	N.S.	2 (22%)
Mohr (2003)[54]	1995-2002	3	Retro	37	Hepatic injury + NOM	33 (16-85)	25	Decompression	1 (3%)	N.S.
Velmahos (2003)[55]	1999-2001	3	Pro	78	Hepatic injury	35 (±12); 35 (±17)	25 (±11); 19 (±10)	N.S.	2 (3%)	N.S.
Cothren (2004)[56]	1996-2003	3	Retro	2,762	ICU and ISS >15	36 (±4)	33 (±4)	IAP >25 mmHg + OD	36 (1%)	14 (39%)
Miller (2004)[57]	2001-2003	3	Pro	212	TL	36 (±15)	34 (±12)	N.S.	8 (4%)	N.S.
Pleva (2004)[58]	1999-2002	5	Retro	436	Polytrauma	N.S.	N.S.	IAP >25mmHg + OD	8 (2%)	2 (25%)
Stone (2004)[59]	2000-2020	3	Retro	890	Trauma ICU	N.S.	25 (±9) (9-45)	N.S.	10 (1%)	6 (60%)
Britt (2005)[60]	1997-2003	5	Retro	10	ACS	40	N.S.	IAH + OD	N.S.	6 (60%)
Miller (2005)[61]	1995-2002	3	Retro	344	TL	36 (±16)	35 (±14)	Elevated IAP + OD	115 (33%)	N.S.
Prince (2005)[62]	1989-1998	3	Retro	920	TL	32 (±16)	22 (±15)	Tense abdomen + OD	12 (1%)	N.S.
Rodas (2005)[63]	2002-2004	5	Retro	5	ACS	32 (±7)	21 (±4)	Decompr. improved OD	N.S.	0 (0%)
Kozar (2006)[64]	2000-2006	3	Retro	699	Blunt hepatic injury	33 (14-90)	27 (±11); 25 (±11)	N.S.	5 (1%)	N.S.
Reed (2006)[65]	2004-2005	5	Retro	226	Trauma ICU	36 (±16)	22	IAP ≥20mmHg	12 (5%)	5 (42%)
Nicol (2007)[66]	1996-2004	3	Retro	72	Hepatic injury + packing	30 (14-68)	N.S.	N.S.	12 (17%)	N.S.
Scalea (2007)[67]	2001-2004	3	Retro	102	Blunt trauma + brain inj.	30 (±12)	34 (±13)	Laparostomy. no abd. injury	24 (24%)	N.S.
Dissanaike (2008)[68]	2004-2007	3	Pro	1,001	Blunt injury	40 (±17); 39 (±18)	34 (±13); 36 (±14)	WSACS	43 (4%)	31 (72%)
Letoublon (2008)[69]	1994-2005	3	Retro	186	Blunt hepatic injury + NOM	33 (7-81)	N.S.	N.S.	4 (2%)	N.S.

Madigan (2008)[70]	2001-2005	5	Retro	48	ACS	41 (±17)	26 (±9)	WSACS	N.S.	29 (60%)
Parsak (2008)[71]	1998-2005	5	Pro	29	IAP >10mmHg	56 (±16) (20-88)	N.S.	WSACS	N.S.	10 (35%)
Wei (2008)[72]	2001-2006	3	Retro	87	Splenic injury	38 (±14); 47 (±19)	34 (±12); 29 (±11)	N.S.	1 (1%)	N.S.
Cotton (2009)[73]	2004-2008	2	Pro	266	Massive transfusion	39 (±18); 36 (±16)	28 (±16) 33 (±16)	IAP >25mmHg + OF	14 (5%)	N.S.
Koss (2009)[74]	2004-2007	3	Retro	23	ACS	40 (±21) (13-85)	32 (±11) (9-50)	N.S.	N.S.	5 (22%)
Nellensteijn (2009)[75]	1990-2008	3	Retro	80	U18 + blunt hepatic injury	12 (2-18)	16.5 (4-57); 16.0 (4-41)	N.S.	1 (1%)	N.S.
Cheatham (2010)[11]	2002-2007	3	Retro	4,938	Laparostomy	40 (±17); 49 (±19)	23 (±11); 30 (±14)	WSACS	95 (2%)	47 (45%)
Duchesne (2010)[76]	2009-2009	5	Pro	5	ACS	36 (±17)	29 (±9)	WSACS	N.S.	0 (0%)
Khan (2010)[2]	2006-2007	3	Pro	38	TL	35 (±15) (18-85)	N.S.	WSACS	5 (13%)	5 (100%)
Balogh (2011)[77]	2007-2009	3	Pro	81	ICU and ISS >15	41 (±2)	29 (±1)	WSACS	0 (0%)	N.S.
Giladi (2011)[78]	2004-2006	3	Retro	4,294	Trauma ICU	39 (±18); 40 (±17)	21 (±12.6); 20 (±12.3)	IAP >25mmHg + OF	74 (2%)	N.S.
James (2011)[79]	2007-2011	2	Pro	109	Massive transfusion	27.6; 35.6; 33.0; 35.7	18; 16; 29.5; 18	N.S.	3 (3%)	N.S.
Parks (2011)[80]	2002-2009	3	Retro	591	Blunt hepatic injury	N.S.	Stratified	N.S.	1 (<1%)	N.S.
Saltzherr (2011)[81]	1995-2008	3	Retro	177	Hepatic injury	29 (19-38)	22 (10-34)	N.S.	1 (<1%)	N.S.
Shekhei (2011)[82]	N.S.	5	Pro	28	ACS	N.S.	N.S.	N.S.	N.S.	23 (82%)
Al-sharif (2012)[83]	2006-2011	3	Retro	139	U18 + ISS >12. no hemorrhage	14 (10-16)	24 (16-30)	N.S.	0 (0%)	N.S.
Ding (2012)[84]	N.S.	5	Retro	39	Laparostomy	N.S.	N.S.	Decompression	N.S.	8 (21%)
Harrell (2012)[85]	2004-2009	5	Retro	87	ACS	N.S.	N.S.	WSACS	N.S.	58 (67%)
Maung (2012)[86]	2007-2010	3	Retro	309	Trauma ventilation	46 (±18); 45 (±20)	21 (±11); 18 (±11)	WSACS	7 (2%)	N.S.
Neal (2012)[20]	2003-2008	3	Pro	452	Massive transfusion	41 (±17)	34 (25-43)	IAP >25cmH2O + OF	68 (15%)	N.S.
Ordonez (2012)[87]	2003-2010	3	Pro	311	Gunshot wounds	30 (±10); 30 (±10)	25 (18-34); 16 (9-25)	N.S.	35 (11%)	N.S.
Pando (2012)[88]	2005-2010	3	Retro	9	Hepatic injury + NOM	N.S.	26 (±8)	N.S.	1 (11%)	0 (0%)
Ali (2013)[89]	2010-2011	3	Pro	100	Abd. injury + pelvic fracture	27 (5-50)	N.S.	WSACS	28 (28%)	23 (82%)
Divarci (2013)[90]	2009-2010	3	Retro	14	U18 Abdominal trauma	N.S.	N.S.	IAP >15 mmHg + OD	2 (14%)	N.S.
Fiard (2013)[91]	2004-2012	3	Retro	27	Renal injury treated + NOM	27(13-63)	N.S.	N.S.	1 (4%)	N.S.
Guidry (2013)[6]	2007-2012	3	Retro	258	Vascular injury	Stratified	Stratified	N.S.	8 (3%)	N.S.
Kasotakis (2013)[92]	2003-2011	3	Retro	1,754	Blunt injury	44 (± 18)	32 (± 13) (1-75)	N.S.	103 (6%)	N.S.
Mahmood (2013)[93]	2009-2011	3	Pro	117	Hemorrhagic shock	35 (± 14)	23 (± 10)	WSACS	1 (1%)	N.S.
Rencuzogullari (2013)[94]	N.S.	2	Pro	40	ACS	N.S.	N.S.	N.S.	N.S.	12 (30%)
Asfar (2014)[95]	2003-2012	3	Pro	117	Blunt hepatic injury	29 (±12) (7-63)	N.S.	N.S.	4 (3 %)	N.S.
Joseph (2014)[96]	2006-2011	3	Retro	799	TL	34 (±17)	20	WSACS	18 (2%)	N.S.

ACS, Abdominal Compartment Syndrome; ICU, Intensive Care Unit; IAH, Intra-Abdominal Hypertension; IAP, Intra-Abdominal Pressure; ISS, Injury Severity Score; LOE, level of evidence (1 = systematic review with or without meta-analysis, 2 = randomized controlled trial, 3 = Cohort study, 4 = Case-control study, 5 = case series, 6 = case report, 7 = opinion); N.S., Not Specified; OD, Organ Dysfunction; OF, Organ Failure; Pro, prospective; Retro, Retrospective; SDC, Supplemental Digital Content; Stratified, population is stratified in multiple groups with differing ISS or age; TL, Trauma Laparotomy; U18, pediatric population under 18 years of age; WSACS, (according to definitions of the) World Society of the Abdominal Compartment Syndrome. *Age (mean or median) is shown in years with corresponding standard deviation (SD) or ranges.

**ISS is shown as mean or median with corresponding SD or ranges unless indicated otherwise. Prevalence and mortality rates are shown as number with corresponding percentage.

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