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Methodological background and strategy for the 2012–2013 updated consensus definitions and clinical practice guidelines from the abdominal compartment society

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Abstract

The Abdominal Compartment Society (www.wsacs.org) previously created highly cited Consensus Definitions/Management Guidelines related to intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS). Implicit in this previous work, was a commitment to regularly reassess and update in relation to evolving research. Two years preceding the Fifth World Congress on Abdominal Compartment Syndrome, an International Guidelines committee began preparation. An oversight/steering committee formulated key clinical questions regarding IAH/ /ACS based on polling of the Executive to redundancy, structured according to the Patient, Intervention, Comparator, and Outcome (PICO) format. Scientific consultations were obtained from Methodological GRADE experts and a series of educational teleconferences were conducted to educate scientific review teams from among the wscacs. org membership. Each team conducted systematic or structured reviews to identify relevant studies and prepared evidence summaries and draft Grades of Recommendation Assessment, Development and Evaluation (GRADE) recommendations. The evidence and draft recommendations were presented and debated in person over four days. Updated consensus definitions and management statements were derived using a modified Delphi method. A writing committee subsequently compiled the results utilizing frequent Internet discussion and Delphi voting methods to compile a robust online Master Report and a concise peer-reviewed summarizing publication. A dedicated Paediatric Guidelines Subcommittee reviewed all recommendations and either accepted or revised them for appropriateness in children. Of the original 12 IAH/ACS definitions proposed in 2006, three (25%) were accepted unanimously, with four (33%) accepted by > 80%, and four (33%) accepted by > 50%, but required discussion to produce revised definitions. One (8%) was rejected by > 50%. In addition to previous 2006 definitions, the panel also defined the open abdomen, lateralization of the abdominal musculature, polycompartment syndrome, abdominal compliance, and suggested a refined open abdomen classification system. Recommendations were possible regarding intra-abdominal pressure (IAP) measurement, approach to sustained IAH, philosophy of protocolized IAP management and same-hospital-stay fascial closure, use of decompressive laparotomy, and negative pressure wound therapy. Consensus suggestions included use of non-invasive therapies for treating IAH/ACS, considering body position and IAP, damage control resuscitation, prophylactic open abdomen usage, and prudence in early biological mesh usage. No recommendations were made for the use of diuretics, albumin, renal replacement therapies, and utilizing abdominal perfusion pressure as a resuscitation-endpoint. Collaborating Methodological Guideline Development and Clinical Experts produced Consensus Definitions/Clinical Management statements encompassing the most contemporary evidence. Data summaries now exist for clinically relevant IAH/ACS questions, which will facilitate future scientific reanalysis.

Key words: intra-abdominal hypertension, abdominal compartment syndrome, critical care, grades of recommendation, assessment, development, and evaluation criteria, evidence-based medicine, abdominal compartment society

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Owing to its restricted capacity to expand, the peritoneal cavity is subject to raised internal pressures like any other anatomic compartment. As pressure within this compartment increases above normal tissue perfusion pressure, the many critical viscera and vascular structures within may be compromised, initiating a cascade of events that may lead to organ dysfunction/failure and ultimately death, if not corrected. Thus, raised intra-abdominal pressure (IAP), which constitutes intra-abdominal hypertension (IAH), has been increasingly recognized as being common and associated with pathology when sought [1–5]. Detrimental physiologic associations with IAH have been recognized in nearly all organ systems, including the cardio-respiratory, renal, neurologic, gastrointestinal, hepatic, and adrenocortical systems; related both to physical and humeral effects, ultimately manifested as the abdominal compartment syndrome (ACS) if overt organ failure ensues [6–8]. Overt ACS is an end-stage manifestation of severe IAH, with a mortality approaching 100% without treatment in some reports [9]. As ACS represents organ failure from IAH, it may still be lethal, despite eventual decompression and correction of the underlying cause [10].

When first re-recognized in contemporary times, severe IAH/ACS was epidemic in severely ill/injured subgroups, such as those with massive intra-abdominal haemorrhage requiring damage control that had their abdomens closed primarily [11, 12]. Secondary ACS was seen in many patients, such as those with massive burns, or even extra-abdominal injuries in the setting of aggressive crystalloid resuscitation [13–15]. However, in the ensuing period of not more than two decades since Kron's sentinel description of the syndrome and its treatment [9], there has been an exponential growth in attention, research, and published material related to both IAH and ACS [16, 17]. Specific milestones along this pathway included the incorporation of the World Society of the Abdominal Compartment Syndrome (WSACS — www.wsacs.org), its bi-annual scientific congresses, and a series of consensus guidelines relating to Definitions [18–20], Management [21], and Methods for Research [22], all produced by the WSACS. Although hard to directly attribute, the WSACS likely shares in the credit along with the United States Military, and Academic Institutions globally in heralding in a new era in resuscitation [23–27]. Concurrent major changes in the science and philosophy of the resuscitation and management of the critically injured/ill also include the wider application of damage control resuscitation for massive haemorrhage [25, 28–33], early goal directed therapy for severe sepsis [34], and an appreciation of the general risks of over hydration [35-37], all appear to have impacted the epidemiology and impact of IAH/ACS in these populations [38]. There have also been very significant paradigm shifts in the early delivery of care relating to both haemostatic and balanced resuscitation, such that it has been suggested that damage control itself may be less important than previously emphasized [39]. These changes are resulting in significant reductions in ACS [40].

The World Society of the Abdominal Compartment Syndrome has always prided itself in being a progressive and relevant organization. As much as success in addressing the most obvious catastrophic pathology of the ACS has become apparent, it has become obvious that widespread understanding of the more complex role of IAH in multi-factorial critical illness/injury has not [41]. Thus, a notable scientific metamorphosis has been the rebranding of the World Society of the Abdominal Compartment Syndrome as the Abdominal Compartment Society, a society promoting cohesive approach to promoting research, fostering education, and improving the survival of patients with intra-abdominal hypertension (IAH) and/or abdominal compartment syndrome (ACS), as well as now embracing the surgery and science of reconstructing the abdominal compartment itself [42, 43]. There are two integral aspects to this rebranding. Firstly, there is a new holistic emphasis on including all clinicians, innovators and technicians, as well as pure scientists interested and involved in studying, manipulating and rehabilitating the abdominal compartment. Secondly, there is a desire to embrace the future while not forgetting the short but remarkable past accomplishments of the wsacs.org, thus providing the impetus to "abbreviate" the Abdominal Compartment Society as the wsacs.org.

In addition to rebranding however, as part of the more serious commitment of the wsacs.org to maintain the currency of its recommendations, the wsacs.org undertook a planned review and update of the previous Consensus Definitions and Management Guidelines to reflect recent advances in both clinical care and basic science [44]. Ambitiously, in order to uphold the highest standards regarding consistency in rating the quality of evidence and in communicating the level of confidence placed in the clinical practice guidelines, the principles of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system for clinical practice guidelines development were adhered to [45–51]. The results were a 200-page-plus resource document available on-line, with a high-level summary published in a highly ranked journal, namely Intensive Care Medicine, and supported by 44 drop-down menus each elaborating on the clinical definition/question of interest [52].

METHODS

GUIDELINES COMMITTEE COMPOSITION AND FUNCTION

The 2012 Guidelines Committee (GC) of the WSACS.org consisted of a Chair, Coordinator, two Methodological Advisors (impartial members of the GRADE Working Group), and eleven (11) systematic review teams. Among the non-methodological advisor GC members, eight were surgeons, who had subspecialty training in trauma and/or acute care surgery, general surgery, or vascular surgery, seven were experts in critical care medicine/anaesthesiology or internal medicine, while five practiced both surgery and critical care medicine. The goal was to provide an updated "state-of-the-art" reference for IAH/ACS-related clinical and basic science research, remembering that the existing definitions have previously been used to define IAH/ACS and related phenomena, wherein unnecessary changes would detract from the goal of diagnostic standardization and external validity.

EVALUATION OF EXISTING EXPERT CONSENSUS DEFINITIONS

The members reviewed, evaluated, and ultimately ratified the latest 2013 expert consensus definitions through ongoing discussion and debate through electronic mail messages and posts upon a dedicated electronic Expert Consensus Definitions Billboard. In concordance with the levels of agreement appropriate for consensus [48], all expert consensus definitions for which more than 80% of the members voted to accept "as is" were retained, while all with less than 50% acceptance were rejected. Definitions with only 50-80% agreement were revised through ongoing discussions until complete consensus was obtained. Where extensive discussion among subspecialists or other experts was required, special sub-committees where created, including a dedicated Paediatric Guidelines Sub-Committee which reviewed the adult guidelines regarding their generalizability to paediatrics and thereafter commented upon this when appropriate. Other special committees included special working groups which were set up to address the issues of abdominal compliance and the risk factors for IAH/ACS.

DEVELOPMENT OF CONSENSUS MANAGEMENT RECOMMENDATIONS

USE OF GRADE AND DEVELOPMENT OF CLINICAL QUESTIONS

We followed the GRADE approach for guideline developers to generate management recommendations related to IAH/ACS from the patient's perspective [45]. Using this approach, GC members first defined specific clinical questions and patient-important outcomes with the assistance of two impartial methodological advisors and members of the GRADE Working Group (R.J., G.H.G.). Questions were formulated according to the Patient, Intervention, Comparator, and Outcome (PICO) format [53], and were based on polling of the WSACS Executive to redundancy concerning their interpretation of the most critical clinical questions in the realm of IAH/ACS. Redundancy means that the development of the questions continued until no new clinical question themes or ideas could be identified. The final 12 clinical questions were thus perceived to reflect the most important management issues facing clinicians and/or those for which the evidence had evolved most rapidly since the 2006 WSACS guidelines (Table 1). The GC then later refined these identified clinical questions of interest during a series of pre-meeting teleconferences with the assistance of the two methodological experts. The GC also reviewed the

Table 1. Most pertinent management questions concerning intra-abdominal hypertension and the abdominal compartment syndrome

1.	**Should we measure IAP?** Does measuring intra-abdominal pressure (IAP) in critically ill or injured patients improve outcomes compared to strategies that do not consider or measure IAP?
2.	**How should we treat/interpret IAP?** Do management strategies that use the abdominal perfusion pressure (APP) to guide management improve patient outcomes compared to strategies that do not consider the APP in critically ill adults with IAH (IAP > 12 mm Hg) in critical care units?
3.	**Should we treat IAH/ACS?** Do overall management strategies attempting to keep standard-state IAP less than 20 mm Hg result in improved patients outcomes compared to management strategies (or the lack thereof) that either accept higher IAPs (or ignore IAP altogether) in critically ill adults in critical care units?
4.	**How should we treat IAH/ACS non-operatively?** Do management strategies that use percutaneous drainage of intra-peritoneal fluid to reduce the IAP in cases of intra-abdominal hypertension improve patient outcomes compared to strategies that do not use percutaneous drainage in critically ill adults in critical care units?
5.	**How should we treat IAH/ACS operatively?** Do management strategies that use decompressive laparotomy to reduce IAP in cases of overt abdominal compartment syndrome (ACS) improve patient outcomes compared to strategies that do not use decompressive laparotomy in critically ill adults in critical care units? i. With the ACS? ii. With grade III-IV ACS but no formal definition of the ACS?
6.	**How should we avoid IAH/ACS? or how should we deal with the open abdomen, OA?** Does the use of a management strategy involving efforts at closing the fascia of an open abdomen (OA) improve patient outcomes compared to strategies that do not use strategies to close the fascia and which thus accept skin graft closures and delayed reconstruction in those critically ill adults with OAs in critical care units?)
7.	**How should we avoid IAH/ACS? or how should we deal with the OA?** Does the use of a management strategy involving abdominal/peritoneal vacuum/suction type dressings improve patient outcomes compared to strategies that do not use peritoneal vacuum drainage in critically ill adults with OAs in critical care units?
8.	**How should we avoid IAH/ACS? or how should we deal with the OA?** Does the use of a management strategy involving efforts at closing the fascia of an open abdomen (OA) improve patient outcomes compared to strategies that do not use strategies to close the fascia and which thus accept skin graft closures and delayed reconstruction in critically ill adults with OAs in critical care units
9.	**How should we avoid IAH/ACS? or how should we deal with the OA?** Does the use of a management strategy involving the early closure with bioprosthethic meshes improve patient outcomes compared to strategies that do not use bioprosthethic meshes and which thus accept skin graft closures and delayed reconstruction in critically ill adults with OAs in critical care units?
10.	**How should we avoid IAH/ACS? or how should we deal with the OA?** Does the use of a management strategy involving component parts separation improve patient outcomes compared to strategies that do not use component parts separation in critically ill adults with OAs in critical care units?
11.	**How should we avoid IAH/ACS?** Does a management strategy attempting to obtain fluid balance in equilibrium, or even a negative state (conservative fluid strategy) after day 3, result in a lower IAP and improved patients outcomes compared to management strategies that either accept a liberal fluid management? Moreover, will use of a more liberal fluid strategy compared to a restrictive strategy the latter result in higher IAPs in critically ill adults in critical care units?
12.	**How should we avoid IAH/ACS?** Does a massive transfusion strategy involving an enhanced ratio of plasma and/or minimizing crystalloid fluids result in a reduced incidence of IAH/ACS and related complications compared to strategies that do not?

WSACS Management Algorithm (Fig. 1) in light of recent developments.

SYSTEMATIC REVIEWS

Systematic review teams subsequently conducted systematic or structured/semi-structured reviews and prepared evidence profiles for each of the identified patient-important outcomes as suggested by GRADE [45, 54, 55]. As the details required to answer the Management question were potentially vast, each team was encouraged to prepare the detailed results as a stand-alone comprehensive review of this topic. To date, the systematic review of negative-pressure wound therapy (NPWT) comparative studies is the only one that has been individually prepared and published after peer review [56], while a systematic review on the deleterious effects of a positive cumulative fluid balance has partially been drafted [57].

EDUCATING THE SYSTEMATIC REVIEW TEAMS

Although the members of each systematic review team were clinical experts in IAH/ACS, with typically extensive experience in Research and Academia, they were not GRADE experts. Thus, in order to educate the teams, GRADE experts from the GRADE Working Group (R.J., G.H.G.) prepared instructional presentations that were hosted on the Guidelines Website for self-study and review. They also hosted two separate Web Seminar type presentations, both repeated at 12-hour time differences to allow for the different time zones that resulted from recruiting worldwide experts. Finally, basic GRADE and Methodological manuscripts were distributed for self-study.

THE SCIENTIFIC EVIDENCE REVIEW AND EVIDENCE SUMMARY CREATION PROCESS

Each Review team was led by a Chair, who was responsible for the conduct of the review, recruiting knowledgeable content experts who had engaged with the GRADE educational process, and for compiling an Evidence Summary and initial recommendations to the overall Committee.

DELIBERATION AND DEVELOPMENT OF CONSENSUS MANAGEMENT RECOMMENDATIONS

Formal face-to-face Expert Consensus Conference meetings for all GC members were held on two separate days immediately preceding and following the 5th Scientific Con-

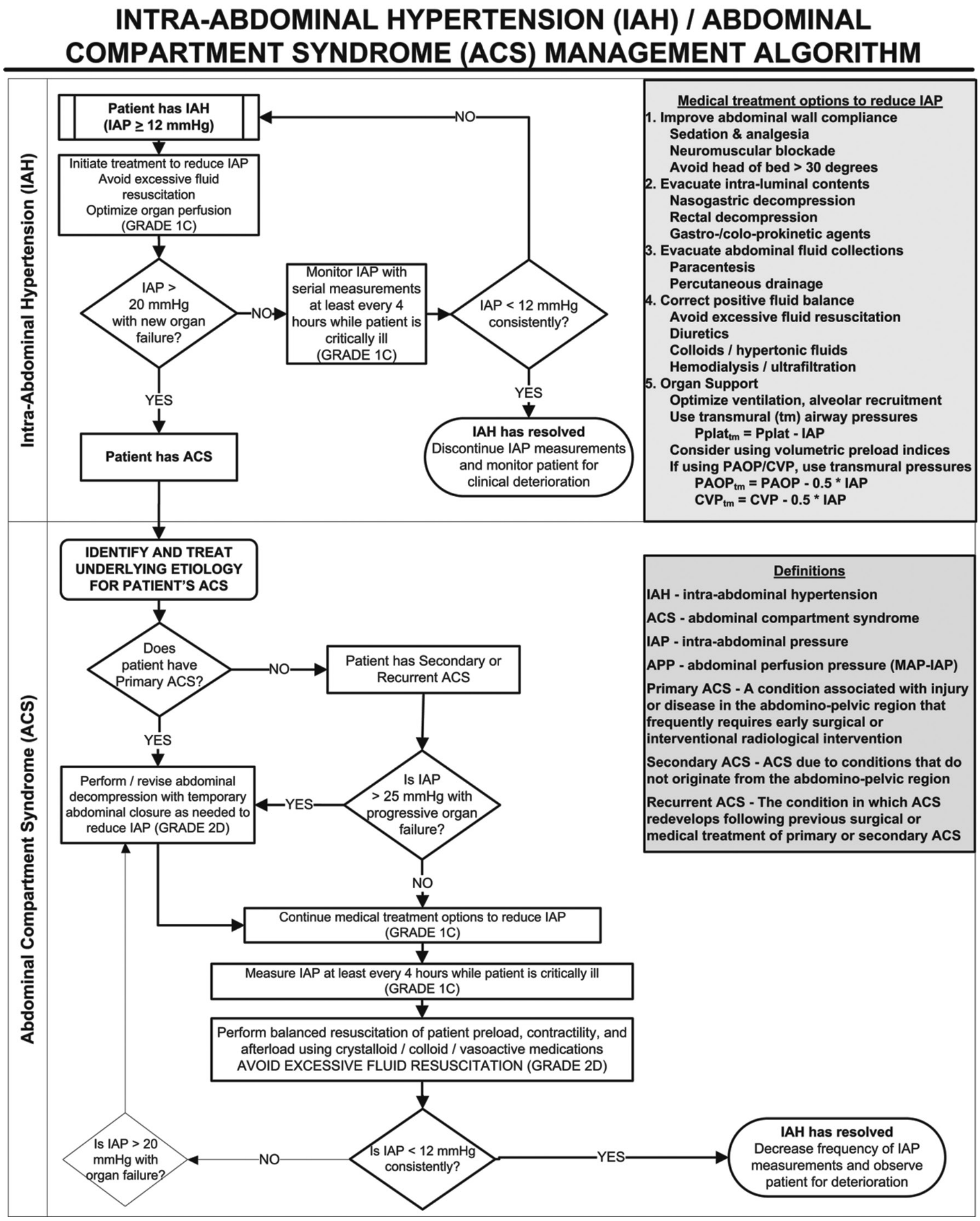

Figure 1. WSACS intra-abdominal hypertension, abdominal compartment syndrome management algorithm introduced in 2007

gress of the WSACS in Orlando, FL, U.S.A on August 10th to 13th, 2011. At the Management Guidelines meeting, each systematic review team presented their search methods and evidence profile to the GC and one of the methodological advisors (R.J.), whose role was to comment on their assessment of the quality of the available evidence. Each team then made recommendations to the Panel regarding the direction (for/against/no recommendation), strength (recommend/suggest), and confidence (on an ordinal scale of 1 to 3) of the recommendation in accordance with GRADE guidelines [45, 55, 58–61].

As recommended by GRADE, randomized controlled trials (RCTs) were considered to represent high-quality evidence and observational studies were considered low-

Table 2. Final 2013 Consensus Definitions of the Abdominal Compartment Society [52]

No.	Definition
Retained Definitions from the Original 2006 Consensus Statements	
1.	IAP is the steady-state pressure concealed within the abdominal cavity
2.	The reference standard for intermittent IAP measurements is via the bladder with a maximal instillation volume of 25 mL of sterile saline
3.	IAP should be expressed in mm Hg and measured at end-expiration in the supine position after ensuring that abdominal muscle contractions are absent and with the transducer zeroed at the level of the mid-axillary line
4.	IAP is approximately 5–7 mm Hg in critically ill adults
5.	IAH is defined by a sustained or repeated pathological elevation in IAP ≥ 12 mm Hg.
6.	ACS is defined as a sustained IAP > 20 mm Hg (with or without an APP < 60 mm Hg) that is associated with new organ dysfunction/failure
7.	IAH is graded as follows:
	Grade I, IAP 12–15 mm Hg
	Grade II, IAP 16–20 mm Hg
	Grade III, IAP 21–25 mm Hg
	Grade IV, IAP > 25 mm Hg
8.	Primary IAH or ACS is a condition associated with injury or disease in the abdomino-pelvic region that frequently requires early surgical or interventional radiological intervention
9.	Secondary IAH or ACS refers to conditions that do not originate from the abdomino-pelvic region
10.	Recurrent IAH or ACS refers to the condition in which ACS redevelops following previous surgical or medical treatment of primary or secondary ACS
11.	APP = MAP – IAP
New Definitions Accepted by the 2012 Consensus Panel	
12.	The polycompartment syndrome is a condition where two or more anatomical compartments have elevated compartmental pressures
13.	Abdominal compliance is a measure of the ease of abdominal expansion, which is determined by the elasticity of the abdominal wall and diaphragm. It should be expressed as the change in intra-abdominal volume per change in intra-abdominal pressure
14.	An Open Abdomen is one that requires a temporary abdominal closure due to the skin and fascia not being closed after laparotomy
15.	Lateralization of the abdominal wall is the phenomenon where the musculature and fascia of the abdominal wall, most exemplified by the rectus abdominus muscles and their enveloping fascia, move laterally away from the midline with time

Where ACS indicates abdominal compartment syndrome; APP — abdominal perfusion pressure; IAH — intra-abdominal hypertension; IAP — intra-abdominal pressure; and MAP — mean arterial pressure

quality evidence, unless modified downward due to risk of bias, imprecision, inconsistency of results, indirectness of evidence, or publication bias. Studies could also be modified upwards due to a large estimated magnitude of effect, evidence of a dose-response, or if confounders were likely to minimize the estimated magnitude of effect. Ultimately, the quality of evidence for each outcome was rated along a four-point ordinal scale in which each evidence grade was symbolized by a letter from D to A: very low (D), low (C), moderate (B), and high (A). Although principally designed for meta-analyses of RCTs, summary-of-findings tables were created whenever possible using GRADEpro version 3.2 and the format used by the American College of Chest Physicians. These tables presented estimates of relative effect as relative risks (RR), with their 95% confidence intervals and anticipated absolute effects as mean differences with their associated 95% confidence intervals. As meta-analyses of randomized trials or high quality observational studies were frequently unavailable, these estimates were often derived from those reported by a single study or across a number of studies. All statistical analyses were conducted using Stata version 12.0 (Stata Corp., College Station, TX, USA).

RESULTS

DEFINITIONS

The final accepted consensus definitions of the WSACS are presented in Table 2. Overall, the GC accepted three of the original 12 definitions unanimously, while one was rejected by more than 50% of the GC. Thus, four were originally accepted by > 80% of the GC, and four were accepted by greater than 50% of the GC, but required discussion to arrive at the presented definitions. The risk factors accepted in 2006 are shown in Table 3.

The subcommittee examining the basis for describing abdominal compliance was able to include its recommendations within the current report. The dedicated sub-committees of the GC tasked with examining the evidence-based risk factors for IAH and to discern the most relevant location for zeroing baseline IAP measurements, recognized the challenges and magnitude of these tasks, and were unable to

Table 3. The 2006 Risk Factors for IAH/ACS. Adapted from Malbrain *et al.* [18]

- Acidosis (pH < 7.2)
- Hypothermia (core temperature < 33°C)
- Polytransfusion (>10 units of packed red blood/24 hours)
- Coagulopathy (platelets < 55000/mm^3 OR activated partial thromboplastin time (APTT) > 2 times normal OR prothrombin time (PTT) < 50% OR international standardised ratio (INR) > 1.5)
- Sepsis (American — European Consensus Conference definitions)
- Bacteraemia
- Intra-abdominal infection/abscess
- Peritonitis
- Liver dysfunction/cirrhosis with ascites
- Mechanical ventilation
- Use of positive end expiratory pressure (PEEP) or the presence of auto-PEEP
- Pneumonia
- Abdominal surgery, especially with tight fascial closures
- Massive fluid resuscitation (> 5 L of colloid or crystalloid 24 hours^{-1})
- Gastroparesis/gastric distention/Ileus
- Volvulus
- Haemoperitoneum/Pneumoperitoneum
- Major burns
- Major trauma
- High body mass index (> 30 kg m^{-2})
- Intra-abdominal or retroperitoneal tumours
- Prone positioning
- Massive incisional hernia repair
- Acute pancreatitis
- Distended abdomen
- Damage control laparotomy
- Laparoscopy with excessive inflation pressures
- Peritoneal dialysis

produce recommendations within the time frame required. Thus, these topics will constitute endeavours of the WSACS, which may constitute the basis for future standalone consensus work.

CHANGES OR ADDITIONS TO THE 2006 CONSENSUS DEFINITIONS

THE OPEN ABDOMEN

The open abdomen continues to be variably defined, even in contemporary reviews, and surveys even among trauma surgeons reveals confusion as to exactly what anatomy constitutes an "open abdomen" [62, 63]. Surveys asking this simple question, however, have noted surprising confusion and disagreement in regards to skin closure without fascial closure, or visceral containment with mesh interposition between fascia with or without skin or soft-tissue closure [62]. Thus, the WSACS defined an open abdomen as one requiring a temporary abdominal closure due to the skin and fascia not being closed after laparotomy. In order to facilitate research in this controversial field, the technical details regarding the type of temporary closure should be explicitly stated.

LATERALIZATION OF THE ABDOMINAL MUSCULATURE

There are many recognized complications of the open abdomen such as entero-atmospheric fistulae; heat, fluid, and protein losses; catabolism; and increased nursing resources; among many others. However, loss of domain, wherein the peritoneal contents no longer reside naturally within the confines of the abdominal wall, may be an overlooked concern. Although not well studied or reported, this phenomenon is increasingly being understood as both influencing the degree of complexity involved in abdominal wall reconstruction, and as an undesirable outcome that temporary abdominal closures (TAC) aim to avoid [64]. Thus, the WSACS defined lateralization of the abdominal wall to refer to the phenomenon whereby the musculature of the abdominal wall, most exemplified by the rectus abdominus muscles, moves laterally away from the midline with time and the pericolic gutters become obliterated [65].

CLASSIFICATION OF THE OPEN ABDOMEN

Planning to successfully and safely close any open abdomen must begin immediately after the abdomen is first left open. It is critical when studies are conducted that they address abdominal closure rates considering the indications for open abdominal management, differing comparators, and that abdominal-closure problems of similar difficulty are compared. Thus a classification scheme of open abdomen complexity is required. Two schemes have been previously proposed, that of Swan [66] and that of Bjorck [67]. The WSACS recognizes two critical complications which should be considered in managing an open abdomen; namely fixation of the abdominal contents, especially of the viscera to the side-walls, and the development of an entero-atmospheric fistula (EAF). The classification of Bjorck was therefore amended to reflect this hierarchy of challenges to the patient (Table 4).

POLYCOMPARTMENT SYNDROME

A polycompartment syndrome is a condition where two or more anatomical compartments have elevated compartmental pressures [68]. A compartment syndrome (CS) is defined as an increased pressure in a closed anatomic space which threatens the viability of enclosed and surrounding tissue [69]. Within the body there are 4 major compartments among many: the head, the chest, the abdomen and the extremities. Within each compartment, a CS can affect individual organs and can be associated with different causal disease states. The abdominal compartment has unique topographic properties because it is "up-stream" from the lower extremities and "down-stream" from the

Table 4. Classification Scheme for the Complexity of the Open Abdomen

1. No Fixation
1A: Clean, no fixation
1B: Contaminated, no fixation
1C: Enteric leak, no fixation
2. Developing Fixation
2A: Clean, developing fixation
2B: Contaminated, developing fixation
2C: Enteric leak, developing fixation
3. Frozen Abdomen
3A: Clean, frozen abdomen
3B Contaminated, frozen abdomen
4. Established entero-atmospheric fistula

This is an update of the original Bjorck [67] classification. Enteric leak describes the situation where there is spillage of enteric contents into the abdomen without established enteric fistula development

chest. Therefore, it may influence the pathophysiology of these compartments. Scalea *et al.* was the first to introduce the term multiple CS (MCS) in a study of 102 patients with increased IAP, intrathoracic (ITP), and intracranial pressure (ICP) after severe brain injury [70]. He suggested that different compartments within the body are not isolated and independent entities but instead are closely connected. Because the term multi or multiple CS is nowadays mostly used in relation to multiple limb trauma with CS needing fasciotomy, the term polycompartment syndrome (PCS) was finally coined in 2007 in order to avoid further confusion [71, 72]. Because of the clinical importance of diverse aspects of PCS, further classification in the future seems warranted. Firstly, PCS can either be primary or secondary or a combination of both, in view of the potential effect on organ function [73]. A primary CS is defined as a pathological rise of CP in a compartment due to physical tissue or organ injury within the compartment (i.e. intracranial haematoma or limb fracture). In secondary CS, there is no primary injury in the affected compartment and symptoms are solely based on pressure transmission from one compartment to another (i.e. ACS that develops following a tension pneumothorax) [74]. Different conditions precipitate the occurrence of PCS: severe burns, massive fluid resuscitation, severe sepsis, or prolonged hypotension.

ABDOMINAL COMPLIANCE

The abdominal compliance quantifies the ease of abdominal expansion and is determined by the elasticity of the anterior and lateral abdominal wall and, to a smaller degree, the diaphragm, whereas the more rigid spine and pelvis only minimally, if at all, affect abdominal elasticity [75–77]. The abdominal compliance changes with variations in abdominal volume. It can be expressed as the slope on a volume-pressure curve and this slope will depend on its position on the abdominal volume-pressure curve. In normal physiological conditions with normal abdominal volumes, an additional predefined abdominal volume will only minimally increase IAP. However, when the abdominal volume is already increased, as in high grade IAH, the same abdominal volume will significantly increase IAP. A reduced abdominal compliance implies that any change in volume increase will result in a greater change in IAP, as found in patients with abdominal burn eschar, tight closure following abdominal surgery, or generally in those with high grade of IAH. A compliant abdomen, however, indicates greater tolerance to changes in intra-abdominal volume as seen in elderly patients with loss of elastic recoil of the abdominal wall, women after childbirth or in the obese after weight loss. Abdominal compliance should be expressed in L mm Hg^{-1}. Thus, the WSCAS defined “abdominal compliance” as a measure of the ease of abdominal expansion, determined by the elasticity of the abdominal wall and diaphragm and is expressed as a change in intra-abdominal volume per change in intra-abdominal pressure [78, 79]. The respiratory changes between end-inspiratory and end-expiratory IAP that can be observed in the IAP tracing are an indirect surrogate marker of abdominal wall compliance [75, 80].

PAEDIATRIC GUIDELINES SUB-COMMITTEE

Akin to the adult situation, the influences of IAH and the occurrence of ACS is being more commonly reported in children [81]. While the original, and now the revised WSACS guidelines may serve as guides for many conditions, they cannot be applied directly to all children [81–83]. The Paediatrics Sub-Committee reviewed these guidelines derived from adult care and considered their applicability for use in paediatrics. The Sub-Committee accepted 10 of the adult definitions as appropriate for paediatric use, rejected 4 as inappropriate and was unable to make a recommendation regarding appropriateness concerning the threshold levels of IAH grades (not to be confused with the GRADE methodology). The sub-committee also reviewed relevant paediatric studies to arrive at the accepted and proposed paediatric definition [44].

A summary of the final accepted Paediatric Definitions is presented in Table 5. For the four definitions rejected, new definitions, specific for paediatric use were proposed. As the threshold cut-off of 20 mm Hg may be too high in certain patients and as APP thresholds of 60mm Hg were definitely considered too high, the Paediatric Sub-Committee of the WSACS defines ACS in children as a sustained elevation in IAP of greater than 10 mm Hg associated with new or worsening organ dysfunction that can be attributed to elevated IAP. Several studies have demonstrated that over-distending the bladder with a priming volume of fluid may lead to

Table 5. Final 2013 Adapted Paediatric Consensus Definitions

Definitions Accepted Without Change from the Adult Guidelines	
1.	Intra-abdominal pressure (IAP) is the steady-state pressure concealed within the abdominal cavity
2.	Abdominal perfusion pressure (APP) = Mean arterial pressure (MAP) minus IAP
3.	Primary ACS is a condition associated with injury or disease in the abdomino-pelvic region that frequently requires early surgical or interventional radiological
4.	Secondary ACS refers to conditions that do not originate from the abdomino-pelvic region
5.	IAP should be expressed in mm Hg and measured at end-expiration in the complete supine position after ensuring that abdominal muscle contractions are absent and with the transducer zeroed at the level of the mid-axillary line
6.	Recurrent ACS refers to the condition in which ACS redevelops following previous surgical or medical treatment of primary or secondary ACS
7.	The polycompartment syndrome is a condition where 2 or more compartments have elevated compartment pressures
8.	An Open Abdomen is one in which the abdominal viscera are exposed to the outside environment or retained by a non-autologous artificial barrier which should be explicitly described
9.	Pathophysiological Classification of the Open Abdomen
	1A: clean, no fixation
	1B: contaminated, no fixation
	1C: enteric leak, no fixation
	2A: clean, developing fixation
	2B: contaminated, developing fixation
	2C: entero-atmospheric/cutaneous fistula, developing fixation
	3: frozen abdomen, no fistula
	4: frozen abdomen with entero-atmospheric/cutaneous fistula
	This allows recognition of the significant increase in morbidity and mortality in the presence of an enteric leak/fistula in the lower grades while maintaining sufficient similarity to the original classification system in order that a comparison with previous studies could be possible
10.	Abdominal wall compliance defines a concept regarding the ease of expansion of the abdominal wall and its contents which is determined by the overall intra-abdominal volume and elasticity of the abdominal wall
Proposed Paediatric Specific Definitions	
1.	ACS in children is defined as a sustained elevation in IAP of greater than 10 mm Hg associated with new or worsening organ dysfunction that can be attributed to elevated IAP
2.	The reference standard for intermittent IAP measurement in children is via the bladder using 1 mL kg^{-1} with a minimal instillation volume of 3 mL and a maximum instillation volume of 25 mL of sterile saline
3.	Normal IAP in critically ill children is approximately 4–10 mm Hg
4.	IAH in children is defined by a sustained or repeated pathological elevation in IAP > 10 mm Hg

erroneous readings [84–87]. This was the reason behind reducing the recommended priming volume in adults. A prospective study involved 96 pediatric patients in whom intra-abdominal pressure - bladder volume curves were generated. From this study minimum optimal volumes of 3 mL for bladder instillations were determined for children. This study also determined normal IAP in critically ill children to be 7 ± 3 mm Hg [83]. Thus, the Paediatric Sub-Committee of the WSACS defines the reference standard for intermittent IAP measurement in children as being via the bladder using 1 mL kg^{-1}, with a minimal instillation volume of 3 mL and a maximum instillation volume of 25 mL of sterile saline. The Paediatric Sub-Committee of the WSACS further defines normal IAP in critically ill children as being approximately 4–10 mm Hg and defines IAH in children as being a sustained or repeated pathological elevation in IAP > 10 mm Hg. Although the data is limited in quality, it is well known that all physiologic pressures are generally lower in children than in adults, including IAP, even during critical illness [83].

CONSENSUS MANAGEMENT STATEMENTS

The PICO structured questions are presented in Table 6. The final accepted Consensus Management Statements are summarized in Table 7 and Figure 2, while a further in-depth discussion may be accessed via the online supplemental material accompanying the 2013 revised consensus definitions and management guidelines [44]. Table 8 lists the opinions of the Paediatric Care Sub-Committee Regarding the suitability of the WSACS Management Recommendations for the care of children. In each source document, each clinical question has been presented with a format that includes an overview of the background (narrative), evidence summary,

Table 6. Overview of Structured Clinical Questions

Section	No., Informal Question	PICO Question				
		Population	Interventions	Comparator	Outcomes	Methodology
ICU patients at risk for IAH or ACS	1) Whether to measure IAP	ICU patients	IAP measurement	No IAP measurement	Mortality, length of hospital or ICU stay, acute renal failure	RCTs, observational studies
ICU patients with IAH	2) Whether to use APP to guide management	ICU patients with IAH	IAH management strategies that use APP	IAH management strategies that do not consider APP	Mortality, length of hospital or ICU stay, acute renal failure	RCTs, observational studies
ICU patients	3) Whether to keep fluid balance neutral or even negative	ICU patients	Strategy attempting to obtain a neutral or even negative fluid balance after ICU day 3	A comparatively more liberal fluid management strategy	Mortality, length of hospital or ICU stay, acute renal failure, ACS, IAP	RCTs, observational studies
Critically injured trauma patients with massive haemorrhage	4) Whether to use damage control resuscitation	Critically injured trauma patients with massive haemorrhage	Damage control resuscitation (permissive hypotension, higher ratios of PRBCs to platelets and plasma, and limited crystalloids)	No damage control resuscitation	Mortality, length of hospital or ICU stay, IAP, ACS	RCTs, observational studies
ICU patients with IAH or ACS	5) Whether to use a percutaneous drainage catheter	ICU patients with IAH or ACS	Percutaneous catheter drainage of intra-abdominal fluid	Usual care	Mortality, length of hospital or ICU stay, development of ACS or requirement for decompressive laparotomy, acute renal failure, effect on IAP	RCTs, observational studies
ICU patients with IAH	6) Whether to keep IAP less than 20 mm Hg	ICU patients with IAH	Strategy aimed at keeping IAP less than 20 mm Hg	No IAP management strategy	Mortality, length of hospital or ICU stay, ACS, requirement for decompressive laparotomy, acute renal failure, health-related quality of life	RCTs, observational studies
ICU patients with IAH	7) Whether to treat IAH operatively	ICU patients with IAH	Decompressive laparotomy	No decompressive laparotomy	Mortality, length of hospital or ICU stay, acute renal failure	RCTs, observational studies
Trauma or surgery patients requiring open abdominal management	8) Whether to close the fascia or utilize a planned ventral hernia	ICU patients with open abdominal wounds	Fascial closure during the hospital stay	Use of the planned ventral hernia, skin grafts, and/or delayed fascial closure	Mortality, primary fascial closure, length of hospital and ICU stay, abdominal fistulae, intra-abdominal infection, IAH, ACS	RCTs, observational studies
	9a) Whether to use NPWT for temporary abdominal closure	Trauma or surgery patients requiring open abdominal management	ABThera open abdomen NPT system, KCI VAC, or Barker's vacuum pack technique	Any other TAC technique		
	9b) Whether to use commercial NPWT for temporary abdominal closure	Same	ABThera open abdomen NPT system, KCI VAC	Barker's vacuum pack technique		
	9c) Choice of commercial NPWT for temporary abdominal closure	Same	ABThera open abdomen NPT system, KCI VAC	ABThera open abdomen NPT system, KCI VAC		
	10) Whether to use bioprosthetic meshes	Trauma or surgery patients with open abdominal wounds	Bioprosthetic meshes	No bioprosthetic meshes		
	11) Whether to use acute component parts separation	Trauma or surgery patients with open abdominal wounds	Acute component parts separation	No component parts separation		

Where ACS indicates abdominal compartment syndrome; APP — abdominal perfusion pressure; IAH — intra-abdominal hypertension; IAP — intra-abdominal pressure; ICU — intensive care unit; KCI — Kinetic Concepts Incorporated; NPT — negative pressure therapy; NPWT — negative pressure wound therapy; RCTs — randomized controlled trials; VAC — vacuum-assisted closure

Table 7. Final 2013 WSACS.org Consensus Management Statements

Recommendations	
1.	We recommend measuring IAP when any known risk factor for IAH/ACS is present in a critically ill or injured patient [GRADE 1C]
2.	Studies should adopt the trans-bladder technique as the standard IAP measurement technique [not graded]
3.	We recommend use of protocolized monitoring and management of IAP versus not [GRADE 1C]
4.	We recommend efforts and/or protocols to avoid sustained IAH among critically ill or injured patients [GRADE 1C]
5.	We recommend decompressive laparotomy in cases of overt ACS compared to strategies that do not use decompressive laparotomy in critically ill adults with ACS [GRADE 1D]
6.	We recommend that among ICU patients with open abdominal wounds, conscious and/or protocolized efforts be made to obtain an early or at least same hospital stay abdominal fascial closure [GRADE 1D]
7.	We recommend that among critically ill/injured patients with open abdominal wounds, strategies utilizing negative pressure wound therapy should be used versus those that do not [GRADE 1C]
Suggestions	
1.	We suggest that critically ill or injured patients receive optimal pain and anxiety relief [GRADE 2D]
2.	We suggest brief trials of neuromuscular blockade as a temporizing measure in the treatment of IAH [GRADE 2D]
3.	We suggest that the potential contribution of body position to elevated IAP be considered among patients with, or at risk of, IAH or ACS [GRADE 2D]
4.	We suggest using a protocol to try and avoid a positive cumulative fluid balance in the critically ill or injured patient with, or at risk of, IAH after the acute resuscitation has been completed and the inciting issues/source control have been addressed [GRADE 2C]
5.	We suggest the use of an enhanced ratio of plasma/packed red blood cells for resuscitation of massive haemorrhage versus paying little or no attention to plasma/packed red blood cell ratios [GRADE 2D]
6.	We suggest the use of PCD to remove fluid (in the setting of obvious intraperitoneal fluid) in those with IAH/ACS when this is technically possible compared to doing nothing [GRADE 2C]. We also suggest using PCD to remove fluid (in the setting of obvious intraperitoneal fluid) in those with IAH/ACS when this is technically possible compared to immediate decompressive laparotomy, as this may alleviate the need for decompressive laparotomy [GRADE 2D]
7.	We suggest that patients undergoing laparotomy for trauma suffering from physiologic exhaustion be treated with the prophylactic use of the open abdomen versus intraoperative abdominal fascial closure and expectant IAP management [GRADE 2D]
8.	We suggest not routinely utilizing the open abdomen for patients with severe intraperitoneal contamination undergoing emergency laparotomy for intra-abdominal sepsis unless IAH is a specific concern [GRADE 2B]
9.	We suggest that bioprosthetic meshes should not be routinely used in the early closure of the open abdomen compared to alternative strategies [GRADE 2D]
No Recommendations	
1.	We could make no recommendation regarding use of abdominal perfusion pressure in the resuscitation/management of the critically ill/injured
2.	We could make no recommendation regarding use of diuretics to mobilize fluids in hemodynamically stable patients with IAH after the acute resuscitation has been completed and the inciting issues/source control have been addressed
3.	We could make no recommendation regarding the use of renal replacement therapies to mobilize fluid in hemodynamically stable patients with IAH after the acute resuscitation has been completed and the inciting issues/source control have been addressed
4.	We could make no recommendation regarding the administration of albumin versus not doing so to mobilize fluid in hemodynamically stable patients with IAH after the acute resuscitation has been completed and the inciting issues/source control have been addressed
5.	We could make no recommendation regarding the prophylactic use of the open abdomen in non-trauma acute care surgery patients with physiologic exhaustion versus closing and expectant IAP management
6.	We could make no recommendation regarding use of an acute component separation technique versus not doing so, in order to facilitate earlier abdominal fascial closure

ACS — abdominal compartment syndrome; IAP — intra-abdominal pressure; IAH — intra-abdominal hypertension; PCD — percutaneous catheter drainage

presentation structure previously employed by the American College of Chest Physicians. The consensus management statements currently represent the most thoughtful analysis of the available data and consideration of patient and societal factors that could be made by the Voting panel of the WSACS. Overall, the evidence was generally weak, and represented a “call to arms” to all clinician/scientists in order to attempt to improve the evidence base to allow more informed bedside management. This presents one of the great strengths of the GRADE methodology which, while typically associated with the analysis of high-level scientific evidence [51, 88, 89], is also equally applicable to important clinical questions in which the evidence base is not robust [50].

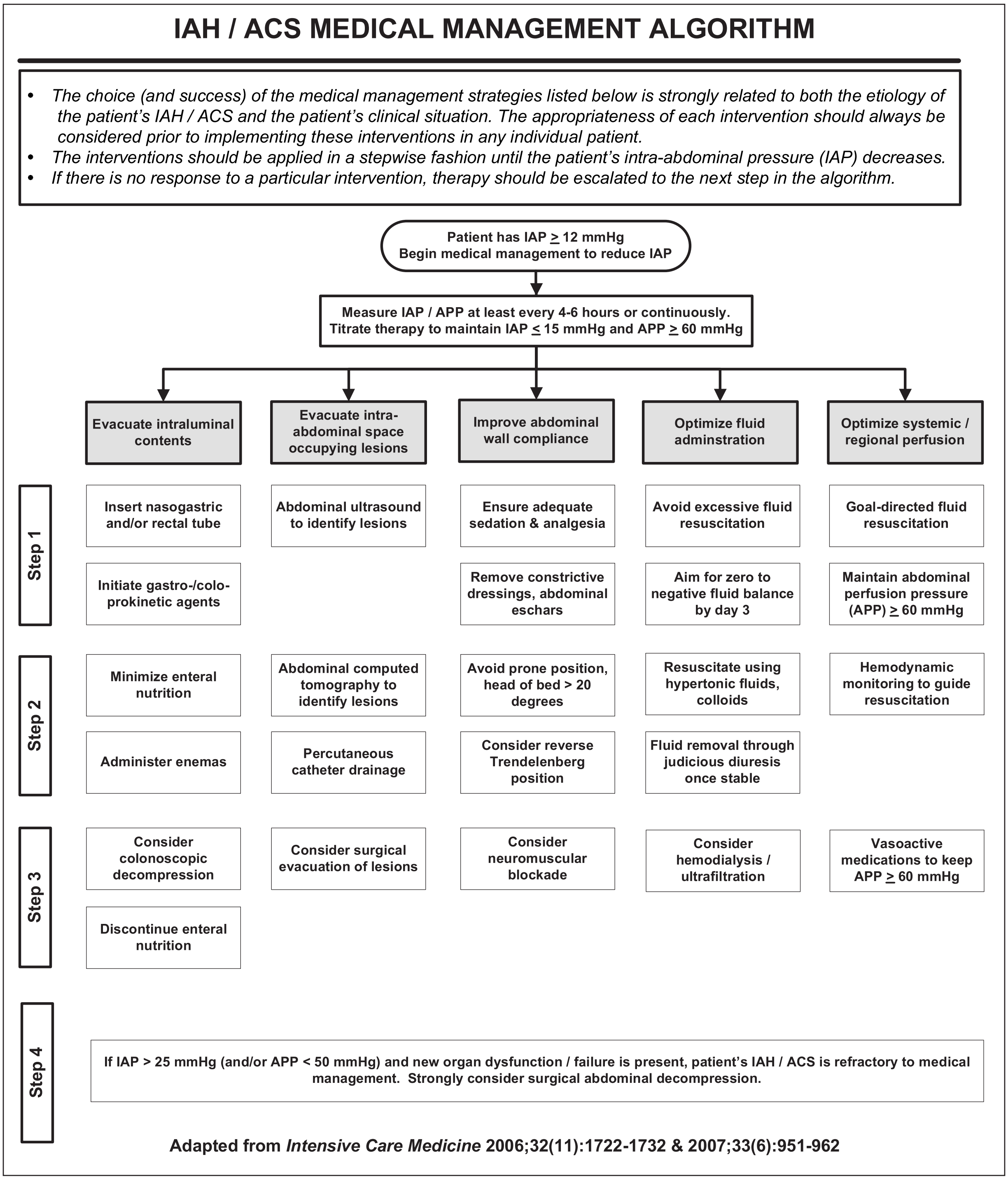

Figure 2. WSACS intra-abdominal hypertension medical management algorithm

DISCUSSION AND CONCLUSIONS

As a result of this rigorous but somewhat complex process, the Abdominal Compartment Society (WSACS.org) was able to present updated consensus definitions and recommendations relevant for IAH/ACS in the second decade of the 21st Century [52]. However, the Abdominal Compartment Society is aware that there are continuous developments in medical knowledge and that much scientific study continues worldwide in all disciplines in general, as well focusing on IAH/ACS specifically. Another great benefit of utilizing the GRADE methodological approach is that dedicated scientific review panels have produced meticulous evidence profiles that now constitute a WSACS Resource that may be augmented and reanalysed at regular future

Table 8. Opinions of the Paediatric Care Sub-Committee Regarding the Suitability of the WSACS Management Recommendations for the care of children

Recommendations accepted as appropriate	
1	Measure IAP when any known risk factor is present in a critically ill/injured patient
2	A protocolized monitoring and management of intra-abdominal pressure should be utilized when caring for the critically ill/injured
3	Use percutaneous drainage to remove fluid in those with IAH/ACS when this is technically possible whether the alternative is doing nothing or a decompressive laparotomy
4	Use DCL to reduce IAP in cases of overt ACS
5	Negative pressure therapy should be utilized to facilitate earlier fascial closure
6	Use a protocol to try to avoid a positive cumulative fluid balance in the critically ill with, or at risk of IAH
Recommendations not accepted as appropriate for Paediatric Care that were not supported for Adult Care	
1	No recommendation was made regarding the use of the abdominal perfusion pressure as a resuscitation marker
2	No recommendation was made regarding the use of DCL for patients with severe IAH but without formal ACS
3	Biological meshes should NOT be routinely utilized to facilitate early acute fascial closure
4	No recommendation could be made to utilize the component separation technique to facilitate earlier acute fascial closure
5	Use an enhanced ratio of plasma to packed red blood cells during resuscitation from massive haemorrhage
6	Efforts and/or protocols be utilized to obtain early or at least same-hospital-stay fascial closure
Pediatric Guidelines Sub-Committee	
Chair:	Janeth Chiaka Ejike, Loma Linda, California
Members:	Francisco Diaz, MD, Torsten Kaussen, MD, Mudit Mathur, MD, Rebecka Meyers, MD, Donald Moores, MD Michael Sasse, MD

intervals. Thus, future evidence-based scientific reviews will be able to focus on how new developments and data modify the evidence base rather than commencing this work *de novo*, thus enabling the Abdominal Compartment Society mandate to regularly reanalyse the world literature on an ongoing basis [18].

An intangible benefit of this collaboration between epidemiological, methodological and clinical experts has been the education of all parties regarding the realities of each other's disciplines. The Abdominal Compartment Society Executive now appreciates both the limitations and the opportunities regarding IAH/ACS research and has delegated the WSACS.org Research Committee to begin to address the most critical questions. Thus, the WSACS.org hopes to leverage this critical analysis which has been vital to the existing database and to commission critical research in order to better the care of our most critically ill/injured patients.

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