

Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome
The Pediatric Guidelines Sub-Committee for the World Society of the Abdominal Compartment Syndrome

Intensive Care Medicine

ISSN 0342-4642

Intensive Care Med

DOI 10.1007/s00134-013-2906-z

No. 6 JUNE 2013 • VOLUME 39

ICM | THE OFFICIAL JOURNAL OF THE SOCIETY OF CRITICAL CARE MEDICINISTS (SCCM) | **ESICM**

ONLINE FIRST

INTENSIVE CARE MEDICINE

Schneider et al. Choice of renal replacement therapy modality and dialysis dependence after acute kidney injury
Among AKI survivors, initial treatment with intermittent RRT might be associated with higher rates of dialysis dependence than continuous RRT. This finding relies on data from observational trials but is not confirmed from pooled analyses of RCTs.

Vincent & Hajjar. What's new in transfusion policies?
Vincent and Hajjar highlight the need to rethink our transfusion practice in the sickest patients. Rather than defining a threshold approach to transfusion, determinants of transfusion triggers for each individual patient are discussed.

Charron et al. Number of supervised studies required to reach competence in advanced critical care transesophageal echocardiography
In unskilled intensivists, the performance of at least 31 supervised transesophageal echocardiography procedures is required to reach competence in hemodynamic assessment of the ventilated patient.

Springer

Your article is published under the Creative Commons Attribution Non-Commercial license which allows users to read, copy, distribute and make derivative works for noncommercial purposes from the material, as long as the author of the original work is cited. All commercial rights are exclusively held by Springer Science + Business Media. You may self-archive this article on your own website, an institutional repository or funder's repository and make it publicly available immediately.

Andrew W. Kirkpatrick
Derek J. Roberts
Jan De Waele
Roman Jaeschke
Manu L. N. G. Malbrain
Bart De Keulenaer
Juan Duchesne
Martin Bjorck
Ari Leppaniemi
Janeth C. Ejike
Michael Sugrue
Michael Cheatham
Rao Ivatury
Chad G. Ball
Annika Reintam Blaser
Adrian Regli
Zsolt J. Balogh
Scott D'Amours
Dieter Debergh
Mark Kaplan
Edward Kimball
Claudia Olvera
The Pediatric Guidelines
Sub-Committee for the
World Society of the Abdominal
Compartment Syndrome

Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome

Received: 10 February 2013
Accepted: 18 March 2013

© The Author(s) 2013. This article is
published with open access at
Springerlink.com

Members of the listed "Additional group
authorship: the pediatric guidelines sub-
committee" are found in the "Appendix".

Electronic supplementary material

The online version of this article
(doi:10.1007/s00134-013-2906-z) contains
supplementary material, which is available
to authorized users.

A. W. Kirkpatrick (✉)
The Departments of Surgery and Critical
Care Medicine and Regional Trauma
Services Foothills Medical Centre, Calgary,
Alberta T2N 2T9, Canada
e-mail: Andrew.kirkpatrick@
albertahealthservices.ca
Tel.: +1-403-9442888
Fax: +1-403-9448799

D. J. Roberts
Departments of Surgery and Community
Health Sciences, University of Calgary,
Calgary, AB T2N 5A1, Canada
e-mail: Derek.Roberts01@gmail.com

J. De Waele
Department of Critical Care Medicine,
Ghent University Hospital and Ghent
Medical School, Ghent, Belgium
e-mail: jan.dewaele@UGent.be

R. Jaeschke
Departments of Medicine and Clinical
Epidemiology and Biostatistics, McMaster
University, Hamilton, ON L8P 3B6, Canada
e-mail: jaeschke@mcmaster.ca

M. L. N. G. Malbrain
Intensive Care Unit and High Care Burn
Unit, Ziekenhuis Netwerk Antwerpen, ZNA
Stuivenberg, Lange Beeldekenstraat 267,
2060 Antwerpen 6, Belgium
e-mail: manu.malbrain@skynet.be

B. De Keulenaer · A. Regli
Intensive Care Unit, Fremantle Hospital,
Alma Street, PO Box 480, Fremantle, WA
6959, Australia
e-mail: bdekeul@hotmail.com

J. Duchesne
Section of Trauma and Critical Care
Surgery, Division of Surgery, Anesthesia
and Emergency Medicine, Tulane Surgical
Intensive Care Unit, 1430 Tulane Ave.,
SL-22, New Orleans, LA 70112-2699, USA
e-mail: jduchesn@tulane.edu

M. Bjorck
Department of Surgical Sciences, Vascular
Surgery, Uppsala University, Uppsala,
Sweden
e-mail: martin@bjorck.pp.se

A. Leppaniemi
Department of Abdominal Surgery,
Meilahti Hospital, University of Helsinki,
Haartmaninkatu 4, PO Box 340, 00029
Helsinki, Finland
e-mail: ari.leppaniemi@hus.fi

J. C. Ejike
Loma Linda University Children's Hospital,
11175 Campus Street, Ste A1117, Loma
Linda, CA, USA
e-mail: jejike@llu.edu

M. Sugrue
Letterkenny Hospital and the Donegal
Clinical Research Academy, Donegal
Hospital, Galway, Ireland
e-mail: acstrauma@hotmail.com

M. Cheatham
Department of Surgical Education, Orlando
Regional Medical Center, 86 West
Underwood St, Suite 201, Orlando, FL
32806, USA
e-mail: Michael.cheatham@
orlandohealth.com

R. Ivatury
Medical College of Virginia, 417 11 St,
Richmond, VA, USA
e-mail: rivatury@mcvh-vcu.edu

C. G. Ball
Regional Trauma Services, EG 23 Foothills
Medical Centre, Calgary, AB T2N 2T9,
Canada
e-mail: ball.chad@gmail.com

A. Reintam Blaser
Clinic of Anaesthesiology and Intensive
Care, University of Tartu, Puusepa 8, 51014
Tartu, Estonia
e-mail: annika.reintam.blaser@ut.ee

A. Regli
School of Medicine and Pharmacology, The
University of Western Australia, Crawley,
WA 6009, Australia
e-mail: Adrian.regli@gmail.com

A. Regli
School of Medicine, The University of
Notre Dame, Fremantle, WA 6959,
Australia

Z. J. Balogh
John Hunter Hospital, University of
Newcastle, Newcastle, NSW 2310,
Australia
e-mail: Zsolt.balogh@
hne.health.nsw.gov.au

S. D'Amours
Trauma Department, Liverpool Hospital,
Locked Bag 1871, Liverpool, NSW BC
2170, Australia
e-mail: Scott.Damours@swsahs.nsw.gov.au

D. Debergh
Department of Intensive Care, Ghent
University Hospital, 9000 Ghent, Belgium
e-mail: dieter.debergh@UGent.be

M. Kaplan
Albert Einstein Medical Center,
Philadelphia, PA 19141, USA
e-mail: kaplanm@einstein.edu

E. Kimball
Department of Surgery, University of Utah,
50 N Medical Drive, Salt Lake City, UT,
USA
e-mail: Edward.kimball@hsc.utah.edu

C. Olvera
The American British Cowdray Medical
Center, Universidad Anahuac, Mexico City,
Mexico
e-mail: claudia_olvera@me.com

Abstract Purpose: To update the World Society of the Abdominal Compartment Syndrome (WSACS) consensus definitions and management statements relating to intra-abdominal hypertension (IAH) and the abdominal compartment syndrome (ACS). **Methods:** We conducted systematic or structured reviews to identify relevant studies relating to IAH or ACS. Updated consensus definitions and management statements were then derived using a modified Delphi method and the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) guidelines, respectively. Quality of evidence was graded from high (A) to very low (D) and management statements from strong RECOMMENDATIONS (desirable effects clearly outweigh potential undesirable ones) to weaker SUGGESTIONS (potential risks and benefits of the intervention are less clear). **Results:** In addition to reviewing the consensus definitions proposed in 2006, the WSACS defined the open abdomen, lateralization of the abdominal musculature, polycompartment syndrome, and abdominal compliance, and proposed an open abdomen classification

system. RECOMMENDATIONS included intra-abdominal pressure (IAP) measurement, avoidance of sustained IAH, protocolized IAP monitoring and management, decompressive laparotomy for overt ACS, and negative pressure wound therapy and efforts to achieve same-hospital-stay fascial closure among patients with an open abdomen. SUGGESTIONS included use of medical therapies and percutaneous catheter drainage for treatment of IAH/ACS, considering the association between body position and IAP, attempts to avoid a positive fluid balance after initial patient resuscitation, use of enhanced ratios of plasma to red blood cells and prophylactic open abdominal strategies, and avoidance of routine early biologic mesh use among patients with open abdominal wounds. NO RECOMMENDATIONS were possible regarding monitoring of abdominal perfusion pressure or the use of diuretics, renal replacement therapies, albumin, or acute component-parts separation. **Conclusion:** Although IAH and ACS are common and frequently associated with poor outcomes, the overall quality of evidence available to guide development of RECOMMENDATIONS was generally low. Appropriately designed intervention trials are urgently needed for patients with IAH and ACS.

Keywords Intra-abdominal hypertension · Abdominal compartment syndrome · Critical care · Grading of Recommendations, Assessment, Development, and Evaluation · Evidence-based medicine · World Society of the Abdominal Compartment Syndrome

Introduction

Increased attention to intra-abdominal pressure (IAP), along with changes in the clinical management of critically ill or injured patients, have led to an exponential growth in research relating to intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) in recent years [1, 2]. Milestones have included the incorporation of the World Society of the Abdominal Compartment Syndrome (WSACS; www.WSACS.org), and the Society's publication of IAH and ACS expert consensus definitions in 2006 [3, 4], clinical practice guidelines in 2007 [5], and recommendations for research in 2009 [6]. Changes in the management of critically ill surgical and/or medical patients have included increased use of damage control surgery and resuscitation [7–11], percutaneous catheter-based and other minimally invasive therapies, early goal-directed therapy for severe sepsis [12, 13], and a heightened appreciation of the risks of over-resuscitation [14, 15]. In light of such developments, the WSACS reviewed the literature and updated their proposed 2006 consensus definitions and 2007 management statements. The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system for clinical practice guideline developers was used to provide consistency in identifying and rating the quality of available evidence and the strength of management suggestions and recommendations [16–22]. Although the results of our update is reported concisely here, interested readers may refer to the parent report for details (Supplement 1).

Methods

Evaluation of existing 2006 consensus definitions and risk factors

In concordance with the levels of agreement appropriate for consensus [19], all 2006 expert consensus definitions for which more than 80 % of the members voted to accept “as is” were retained, while all those with less than 50 % acceptance were rejected. Definitions with only 50–80 % agreement were revised through ongoing discussion until complete consensus was obtained. Where extensive discussion among subspecialists or other experts was required, special sub-committees were created, including a dedicated Pediatric Guidelines Sub-Committee who reviewed the adult guidelines to determine their generalizability to pediatrics. We also searched the literature to determine which IAH or ACS risk factors proposed in 2006 are now supported by evidence and developed a consensus open abdomen classification system. Further details are presented in Supplement 2.

Development of consensus management statements

We followed GRADE recommendations for guideline developers in order to generate management statements related to IAH/ACS [18]. Using this approach, guidelines committee members first developed structured clinical questions and then defined patient-important outcomes with the assistance of an independent GRADE methodological advisor (R.J.). Questions were based on polling of the WSACS Executive to redundancy and were formulated according to the Patient, Intervention, Comparison, Outcome, and study Design (PICO) format [23]. 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 [18, 20, 24].

Grading of evidence and development of management statements

After each systematic review team had created their initial evidence profile, formal face-to-face meetings among all guideline committee members were held on two separate days immediately preceding and following the Fifth Scientific Congress of the WSACS in Orlando, FL, USA in August 2011. At the Management Guidelines Meeting, each systematic review team formally presented their search methods and evidence profile. In accordance with GRADE guidelines, they then made recommendations to the panel regarding the direction (for/against/no recommendation) and strength (recommend/suggest) of the proposed statement [16–18, 20, 23–26]. 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). Further details are presented in Supplements 3 and 4.

Results

Existing consensus definitions and risk factors

The 2013 WSACS consensus definitions are presented in Table 1. Changes from the previously published 2006 definitions, and the pertinent rationale for such, are outlined in Supplement 5. Risk Factors for IAH and ACS are shown in Table 2 [2, 4, 7, 27–42].

Classification of the open abdomen

Critical complications which should be considered in managing the open abdomen include [43]: (1) fixation of the

Table 1 Final 2013 consensus definitions of the World Society of the Abdominal Compartment Syndrome

No.	Definition
<i>Retained definitions from the original 2006 consensus statements [13]</i>	
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 mmHg 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 midaxillary line
4.	IAP is approximately 5–7 mmHg in critically ill adults
5.	IAH is defined by a sustained or repeated pathological elevation in IAP \geq 12 mmHg
6.	ACS is defined as a sustained IAP > 20 mmHg (with or without an APP < 60 mmHg) that is associated with new organ dysfunction/failure
7.	IAH is graded as follows Grade I, IAP 12–15 mmHg Grade II, IAP 16–20 mmHg Grade III, IAP 21–25 mmHg Grade IV, IAP > 25 mmHg
8.	Primary IAH or ACS is a condition associated with injury or disease in the abdominopelvic region that frequently requires early surgical or interventional radiological intervention
9.	Secondary IAH or ACS refers to conditions that do not originate from the abdominopelvic region
10.	Recurrent IAH or ACS refers to the condition in which IAH or ACS redevelops following previous surgical or medical treatment of primary or secondary IAH or ACS
11.	APP = MAP – IAP
<i>New definitions accepted by the 2013 consensus panel</i>	
12.	A 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 IAP
14.	The 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

ACS abdominal compartment syndrome, APP abdominal perfusion pressure, IAH intra-abdominal hypertension, IAP intra-abdominal pressure, MAP mean arterial pressure

abdominal contents (especially of the viscera to the peritoneal sidewalls) and (2) development of enteroatmospheric fistulae (EAF). To facilitate comparison of patient groups with similar determinants of outcomes and complications, a classification scheme of open abdomen complexity is

Table 2 Risk factors for intra-abdominal hypertension and abdominal compartment syndrome

Risk factor
<i>Diminished abdominal wall compliance</i>
Abdominal surgery [27–29] Major trauma [27, 30, 31] Major burns Prone positioning [32–34]
<i>Increased intra-luminal contents</i>
Gastroparesis/gastric distention/ileus [35] Ileus Colonic pseudo-obstruction Volvulus
<i>Increased intra-abdominal contents</i>
Acute pancreatitis [28] Distended abdomen Hemoperitoneum/pneumoperitoneum or intra-peritoneal fluid collections [36] Intra-abdominal infection/abscess [37] Intra-abdominal or retroperitoneal tumors Laparoscopy with excessive insufflation pressures Liver dysfunction/cirrhosis with ascites [28] Peritoneal dialysis
<i>Capillary leak/fluid resuscitation</i>
Acidosis [3, 4, 19, 38, 47] Damage control laparotomy Hypothermia [30] Increased APACHE-II or SOFA score [36, 38] Massive fluid resuscitation or positive fluid balance [2, 27, 29–31, 36, 48] Polytransfusion [30]
<i>Others/miscellaneous</i>
Age [29] Bacteremia Coagulopathy Increased head of bed angle [40–42] Massive incisional hernia repair Mechanical ventilation [35] Obesity or increased body mass index [2, 28, 48] PEEP > 10 [28] Peritonitis Pneumonia Sepsis [29, 37] Shock or hypotension [3, 4, 28, 30, 45]

References are shown if the presented risk factor is supported at least to some degree by primary literature. Those unsupported by primary literature are based on clinical judgment and/or pathophysiological rationale. The patient populations included in these studies included major trauma patients, general intensive care unit patients, severe acute pancreatitis patients, severe extremity injury patients, and surgical intensive care unit patients. Moreover, some of these studies addressed only patients that were mechanically ventilated, whereas others included mixed cohorts of patients with different ventilation statuses
APACHE-II acute physiology and chronic health evaluation-II, PEEP positive end expiratory pressure, SOFA sequential organ failure assessment

Table 3 Classification scheme for the complexity of the open abdomen

<i>1 No fixation</i>	
1A:	Clean, no fixation
1B:	Contaminated, no fixation
1C:	Enteric leak, no fixation
<i>2 Developing fixation</i>	
2A:	Clean, developing fixation
2B:	Contaminated, developing fixation
2C:	Enteric leak, developing fixation
<i>3 Frozen abdomen</i>	
3A:	Clean, frozen abdomen
3B:	Contaminated, frozen abdomen
<i>4 Established enteroatmospheric fistula, frozen abdomen</i>	

This is an update of the original Björck [97] classification. Enteric leak describes the situation where there is spillage of enteric contents into the abdomen without established enteric fistula development

presented (Table 3). The rationale for creation of this classification system is outlined in Supplement 6.

Pediatric Guidelines Sub-Committee: definitions

A dedicated pediatric sub-committee evaluated the adult definitions for use among children. A summary of the final accepted pediatric definitions is presented in Table 4. For the four definitions rejected, new definitions were proposed that are specific to pediatric use. The rationale for these definitions is outlined in Supplement 7.

Structured clinical questions and consensus management statements

Consensus management statements are summarized in Table 5. Each of these statements are denoted below to indicate whether they were unchanged from previous guidelines, a new guideline, or revised from previous guidelines [5]. An associated summary of overall management and medical management algorithms are presented in Figs. 1 and 2, respectively. The summary of findings and rationale for each of the following management statements is described in the supporting Supplements.

Should we measure IAP? Should we measure it via the bladder? Should we use an IAP measurement protocol? (Supplement 8)

As clinical examination is inaccurate for detecting raised IAP, IAH and ACS research and management rely upon

Table 4 Final 2013 adapted pediatric consensus definitions

No.	Definition
<i>Definitions accepted without change from the adult guidelines</i>	
1.	IAP is the steady-state pressure concealed within the abdominal cavity
2.	$APP = MAP - IAP$
3.	Primary IAH or ACS is a condition associated with injury or disease in the abdominopelvic region that frequently requires early surgical or interventional radiological intervention
4.	Secondary IAH or ACS refers to conditions that do not originate from the abdominopelvic region
5.	IAP should be expressed in mmHg 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 midaxillary line
6.	Recurrent IAH or ACS refers to the condition in which IAH or ACS redevelops following previous surgical or medical treatment of primary or secondary IAH or ACS
7.	A polycompartment syndrome is a condition where two or more anatomical compartments have elevated compartmental pressures
8.	The open abdomen is one that requires a temporary abdominal closure due to the skin and fascia not being closed after laparotomy
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: enteric leak, developing fixation 3A: clean, frozen abdomen 3B: contaminated, frozen abdomen 4: established enteroatmospheric fistula, frozen abdomen
10.	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
<i>Proposed pediatric specific definitions</i>	
11.	ACS in children is defined as a sustained elevation in IAP of greater than 10 mmHg associated with new or worsening organ dysfunction that can be attributed to elevated IAP
12.	The reference standard for intermittent IAP measurement in children is via the bladder using 1 mL/kg as an instillation volume, with a minimal instillation volume of 3 mL and a maximum installation volume of 25 mL of sterile saline
13.	IAP in critically ill children is approximately 4–10 mmHg
14.	IAH in children is defined by a sustained or repeated pathological elevation in IAP > 10 mmHg

ACS abdominal compartment syndrome, APP abdominal perfusion pressure, IAH intra-abdominal hypertension, IAP intra-abdominal pressure, MAP mean arterial pressure

accurate serial or continuous IAP measurements [44]. Although there is an increasing number of IAP measurement techniques, trans-bladder measurement remains a commonly used method, and was recommended by the WSACS in 2006 due to its simplicity and low cost [3, 45].

Table 5 Final 2013 WSACS 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 as compared to inattention to IAP 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 not [GRADE 1C]

Suggestions

1. We suggest that clinicians ensure 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/ACS [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 liberal use of enteral decompression with nasogastric or rectal tubes when the stomach or colon are dilated in the presence of IAH/ACS [GRADE 1D]
5. We suggest that neostigmine be used for the treatment of established colonic ileus not responding to other simple measures and associated with IAH [GRADE 2D]
6. 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/ACS after the acute resuscitation has been completed and the inciting issues have been addressed [GRADE 2C]
7. We suggest use of an enhanced ratio of plasma/packed red blood cells for resuscitation of massive hemorrhage versus low or no attention to plasma/packed red blood cell ratios [GRADE 2D]
8. We suggest 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]
9. 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]
10. We suggest not to routinely utilize the open abdomen for patients with severe intraperitoneal contamination undergoing emergency laparotomy for intra-abdominal sepsis unless IAH is a specific concern [GRADE 2B]
11. 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 or management of the critically ill or 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 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 have been addressed
4. We could make no recommendation regarding the administration of albumin versus not, to mobilize fluid in hemodynamically stable patients with IAH after acute resuscitation has been completed and the inciting issues 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 intraoperative abdominal fascial closure and expectant IAP management
6. We could make no recommendation regarding use of an acute component separation technique versus not to facilitate earlier abdominal fascial closure

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

Statement

We RECOMMEND measuring IAP versus not when any known risk factor for IAH/ACS is present in critically ill or injured patients (Unchanged Management Recommendation 1 [GRADE 1C]) (Table 2). We also

RECOMMEND that studies of IAH or ACS adopt the trans-bladder technique as a standard IAP measurement technique (Unchanged Management Recommendation 2 [not GRADED]). Finally, we RECOMMEND use of protocolized monitoring and management of IAP versus not (New Management Recommendation 3 [GRADE 1C]).

INTRA-ABDOMINAL HYPERTENSION (IAH) / ABDOMINAL COMPARTMENT SYNDROME (ACS) MANAGEMENT ALGORITHM

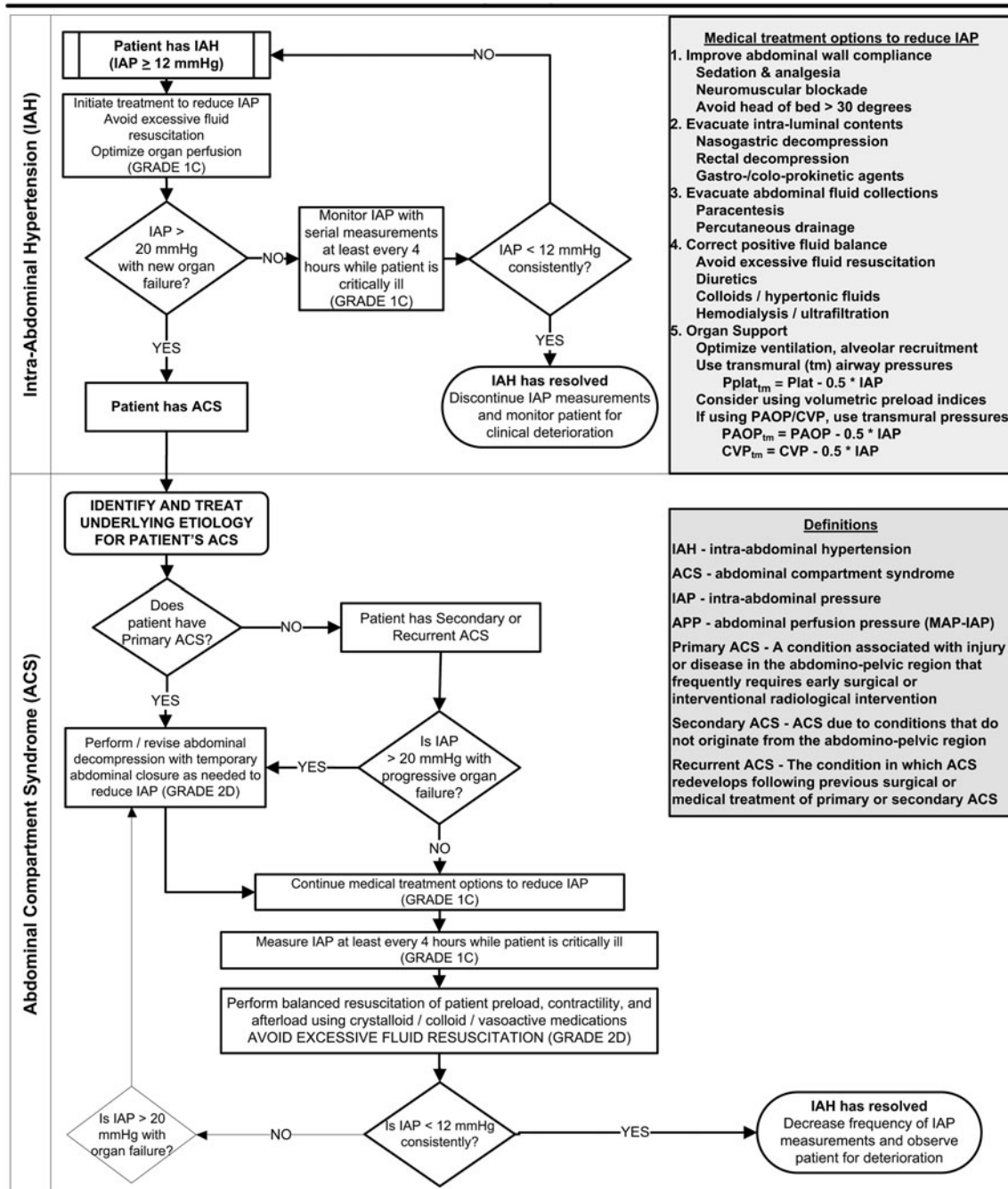


Fig. 1 Updated intra-abdominal hypertension (IAH)/abdominal compartment syndrome (ACS) management algorithm. IAP intra-abdominal pressure

Should we use abdominal perfusion pressure (APP) as a resuscitation endpoint? (Supplement 9)

Abdominal perfusion pressure (APP) may be thought of as the abdominal analogue to cerebral perfusion pressure.

This measure has previously been suggested as a more accurate predictor of visceral perfusion and a better endpoint for resuscitation than IAP or mean arterial pressure (MAP) alone [3, 46].

IAH / ACS MEDICAL MANAGEMENT ALGORITHM

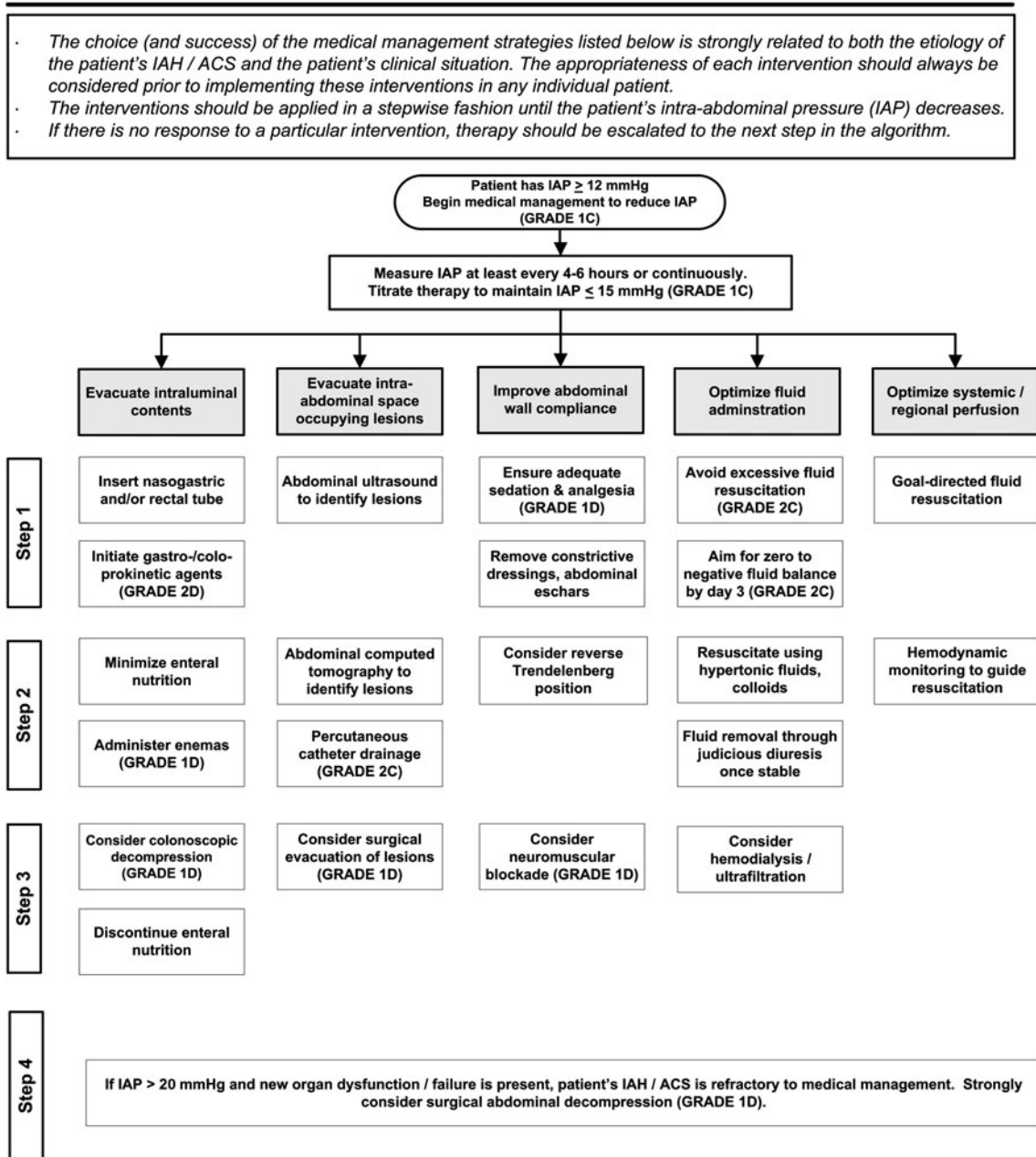


Fig. 2 Updated intra-abdominal hypertension (IAH)/abdominal compartment syndrome (ACS) medical management algorithm. IAP intra-abdominal pressure

Statement

We could make NO RECOMMENDATION regarding use of APP in the resuscitation or management of the critically ill or injured.

Should we treat or prevent IAH? (Supplement 10)

Intra-abdominal hypertension (IAH) has consistently been associated with morbidity and mortality in observational studies. However, it remains uncertain as to whether

treating or preventing this condition improves patient outcomes.

Statement

We RECOMMEND efforts and/or protocols to avoid sustained IAH as compared to inattention to IAP among critically ill or injured patients (New Management Recommendation 4 [GRADE 1C]).

How should we manage IAH/ACS?

In addition to decompressive laparotomy for ACS, numerous medical and minimally invasive therapies have been proposed or studied that may be beneficial for patients with IAH or ACS [47–49]. Approaches or techniques of potential utility include sedation and analgesia, neuromuscular blockade, body positioning, nasogastric/colonic decompression, promotility agents, diuretics and continuous renal replacement therapies, fluid resuscitation strategies, percutaneous catheter drainage (PCD), and different temporary abdominal closure (TAC) techniques among those requiring an open abdomen [5].

Non-invasive options: sedation and analgesia (Supplement 11)

While sedation and analgesia have been incorporated into previous IAH/ACS management algorithms, it remains unclear if they alter outcomes among those with IAH/ACS.

Statement

We SUGGEST that clinicians ensure that critically ill or injured patients receive optimal pain and anxiety relief (Unchanged Management Suggestion 1 [GRADE 2D]).

Neuromuscular blockade (Supplement 12)

Through a reduction in abdominal muscular tone and an increase in abdominal compliance, neuromuscular blockade may reduce IAP among those with IAH and/or ACS [50].

Statement

We SUGGEST brief trials of neuromuscular blockade as a temporizing measure in the treatment of IAH (Unchanged Management Suggestion 2 [GRADE 2D]).

Body positioning (Supplement 13)

Body positioning may change IAP by altering the zero reference for IAP measurement and/or the external forces on the abdominal cavity [32, 40–42, 51].

Statement

We SUGGEST that the potential contribution of body position to elevated IAP be considered among patients with, or at risk of, IAH or ACS (Unchanged Management Suggestion 3 [GRADE 2D]).

Nasogastric/colonic decompression (Supplement 14)

While the routine use of enteric tubes post-operatively has not been associated with benefit after uncomplicated surgery [52, 53], there are anecdotal reports that gastric and colonic distension can induce marked IAH commensurate with ACS [52–56].

Statement

We SUGGEST liberal use of enteral decompression with nasogastric or rectal tubes when the stomach or colon are dilated in the presence of IAH/ACS (New Management Suggestion 4 [GRADE 1D]).

Promotility agents (Supplement 15)

Studies have reported that treatment with neostigmine may be effective at inducing colonic decompression among those with colonic pseudo-obstruction [57]. However, no data exist on the effects of pharmacologic promotility therapy on IAP or outcomes among those with IAH/ACS.

Statement

We SUGGEST that neostigmine be used for the treatment of established colonic ileus not responding to other simple measures and associated with IAH (New Management Suggestion 5 [GRADE 2D]).

Should we keep fluid balance neutral or even negative among ICU patients? (Supplement 16)

An increased or positive fluid balance has been associated with third space fluid accumulation and organ dysfunction

in animal models [58, 59]. However, it remains unknown whether strategies that target a neutral or even negative fluid balance after the initial resuscitation of critically ill patients may be linked with improved clinical outcomes.

Statement

We SUGGEST using a protocol to try to avoid a positive cumulative fluid balance in the critically ill or injured with, or at risk of, IAH/ACS after the acute resuscitation has been completed and the inciting issues have been addressed (New Management Suggestion 6 [GRADE 2C]).

Diuretics (Supplement 17)

Although diuretics are commonly used to improve fluid balance among the critically ill, it remains unknown whether they improve outcomes among those with IAH or ACS.

Statement

We could make NO RECOMMENDATION regarding the use of diuretics to mobilize fluids in hemodynamically stable patients with IAH after acute resuscitation has been completed and the inciting issues have been addressed.

Renal replacement therapies (Supplement 18)

Renal replacement therapies are increasingly being used to modify fluid balance among the critically ill.

Statement

We could make NO RECOMMENDATION regarding the use of renal replacement therapies to mobilize fluid in hemodynamically stable patients with IAH after acute resuscitation has been completed and the inciting issues have been addressed.

Albumin (Supplement 19)

Albumin is frequently administered to critically ill patients in order to expand plasma volume and improve oncotic pressure [60].

Statement

We could make NO RECOMMENDATION regarding the administration of albumin versus not, to mobilize fluid in hemodynamically stable patients with IAH after acute resuscitation has been completed and the inciting issues have been addressed.

Should we use damage control resuscitation? (Supplement 20)

Damage control resuscitation is increasingly being used among critically injured patients [7, 8, 10, 61]. This type of resuscitation is characterized by permissive hypotension, limitation of crystalloid intravenous fluids, and delivering higher ratios of plasma and platelets to red blood cells [8].

Statement

We SUGGEST use of an enhanced ratio of plasma/packed red blood cells for resuscitation of massive hemorrhage versus low or no attention to plasma/packed red blood cell ratios (New Management Suggestion 7 [GRADE 2D]).

Minimally-invasive options

If the medical management approaches suggested above do not alleviate IAH, then clinicians will need to consider whether invasive treatments may be necessary.

Should we use PCD? (Supplement 21)

Although paracentesis has long been a diagnostic and therapeutic procedure among those without documented IAH, the insertion of an indwelling PCD catheter in an attempt to improve IAP and associated patient-important outcomes among those with IAH/ACS was only first suggested in 2001 [62].

Statement

We SUGGEST use of PCD to remove fluid (in the setting of obvious intra-peritoneal fluid) in those with IAH/ACS when this is technically possible compared to doing nothing (Unchanged Management Suggestion 8 [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 (Revised Management Suggestion 8 [GRADE 2D]).

Invasive options: should we use decompressive laparotomy for IAH or ACS?

Decompressive laparotomy historically constituted the standard method to treat severe IAH/ACS and to protect against their development in high risk situations (e.g., following damage control laparotomy for significant intra-peritoneal injury) [63, 64]. It has been reported to result in an immediate decrease in IAP and in improvements in organ function [65, 66]. However, decompressive laparotomy is associated with multiple complications and overall reported patient mortality is considerable (up to 50 %), even after decompression [66].

Statement

We RECOMMEND decompressive laparotomy in cases of overt ACS compared to strategies that do not use decompressive laparotomy in critically ill adults with ACS (Unchanged Management Recommendation 5 [GRADE 1D]).

Use of the open abdomen after trauma damage control laparotomy

The damage control approach to trauma involves an abbreviated resuscitative surgical approach with the primary goal being rapid control of hemorrhage and contamination with restoration of metabolic function at the expense of normal anatomy [8, 63, 64, 67, 68]. Damage control laparotomy is typically a component of a larger damage control approach that includes damage control resuscitation. Although it remains difficult to prove that this approach improves mortality and other outcomes, it has been associated with unexpected patient survival [69, 70].

Statement

We SUGGEST that patients undergoing laparotomy for trauma suffering from physiologic exhaustion be treated with the prophylactic use of the open abdomen versus closure and expectant IAP management (New Management Suggestion 9 [GRADE 2D]).

Damage control laparotomy for non-trauma acute care surgery patients

While damage control techniques are being used among non-trauma acute care surgery patients (which largely includes emergency general surgery) [70, 71], very little evidence exists to support their use, or to support prophylactic open abdominal management afterwards.

Statement

We could make NO RECOMMENDATION regarding the prophylactic use of the open abdomen in non-trauma acute care surgery patients with physiological exhaustion versus intra-operative abdominal fascial closure and expectant IAP management.

Damage control surgery for patients with intra-abdominal sepsis

Intra-abdominal sepsis is a particularly devastating and common form of sepsis, which is commonly associated with development of IAH/ACS [72–74].

Statement

We SUGGEST NOT to routinely utilize the open abdomen approach for patients with severe intra-peritoneal contamination undergoing emergency laparotomy for intra-abdominal sepsis unless IAH is a specific concern (New Management Suggestion 10 [GRADE 2B]).

Definitive abdominal closure

While the open abdomen method is a valuable, life-saving tool, the longer the abdomen is open, the greater the potential for morbidity [43, 75–77]. Thus, specific strategies should be utilized from the first laparotomy that consider prevention of visceral adhesions, loss of soft tissue coverage, lateralization of the abdominal musculature and its fascia, malnutrition, and enteric fistulae [43, 76]. The detailed management of the open abdomen is beyond the scope of this document, for which other recent reviews are available [55, 75, 76, 78].

Should we attempt to achieve same-hospital-stay closure of the open abdomen?

As the inability to achieve primary fascial closure after damage control laparotomy has been associated with

increased morbidity and reduced quality of life among critically ill adults, efforts to close the abdominal fascia before discharge could potentially lead to improved outcomes.

Statement

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 (New Management Recommendation 6 [GRADE 1D]).

Should we preferentially use negative pressure wound therapy (NPWT) for temporary abdominal closure after damage control laparotomy?

Abdominal NPWT involves applying some degree of suction to an open abdominal wound, using techniques that can be home-made or proprietary. Through use of a visceral drape and constant negative wound pressure, this technique prevents visceral adherence to the anterolateral abdominal wall while maintaining medial fascial traction, which may enhance fascial closure rates among those with an open abdomen [29, 79, 80]. It may also remove fluid and pro-inflammatory cytokines from the peritoneum, which may reduce abdominal third space volume, the systemic inflammatory response, and resultant organ dysfunction [29, 77–79, 81, 82]. However, others have reported concerns over associations between NPWT and recurrent ACS or intestinal or enteroatmospheric fistulae [83, 84], especially among those with limited intra-abdominal fluid available for removal [85].

Statement

We RECOMMEND that among critically ill or injured patients with open abdominal wounds, strategies utilizing negative pressure wound therapy should be used versus not (New Management Recommendation 7 [GRADE 1C]).

Should we use component separation to facilitate early fascial closure of the open abdomen?

The component separation technique of the abdominal wall musculature may be used to close an already open abdomen, or to avoid an open abdomen without inducing IAH. An acute component separation technique is defined as one performed during the initial hospitalization [78].

Statement

We could make NO RECOMMENDATION regarding use of an acute component separation technique versus not to facilitate early abdominal fascial closure.

Should we use bioprosthetic mesh closures to achieve closure of the open abdomen?

Advances in tissue recovery and engineering have driven production of a large range of bioprosthetic mesh prostheses that provide new options for abdominal wall reconstruction [86–88]. It has been suggested that these meshes can be used to achieve earlier abdominal fascia closure among those with an open abdomen as they may allow for an increased intra-peritoneal domain without enteric fistula formation [89, 90].

Statement

We SUGGEST that bioprosthetic meshes SHOULD NOT be routinely used in the early closure of the open abdomen compared to alternative strategies (New Management Suggestion 11 [GRADE 2D]).

Pediatric IAH and ACS management

The Pediatric Sub-Committee of the WSACS reviewed the main management guidelines in regard to their applicability and suitability for children. They accepted six guidelines as is, rejected none, but could not make recommendations regarding the suitability for children in the remaining six. Their specific opinions are presented in Table 6.

Discussion

In this manuscript, the WSACS presented updated consensus definitions and management statements related to IAH/ACS. It was identified that there were topics for which future review was required, including the most accurate/meaningful reference-standard locations for IAP measurement and the definition of “normal” values of IAP across various patient populations. Moreover, although the Pediatric Sub-Committee reviewed and made recommendations regarding the appropriateness of the updated consensus definitions and management statements for pediatric patients, further work in this area is needed. Similarly, normal values of IAP among obese

Table 6 Opinions of the Pediatric Guidelines Sub-Committee regarding the suitability of the WSACS management recommendations for the care of children

Statements accepted as appropriate

1. Measure IAP when any known risk factor is present in a critically ill or injured patient
2. Protocolized monitoring and management of IAP should be utilized when caring for the critically ill or injured
3. Use percutaneous catheter drainage to remove fluid in those with IAH/ACS when this is technically possible, whether an alternative is doing nothing or decompressive laparotomy
4. Use decompressive laparotomy in cases of overt ACS
5. Negative pressure wound therapy should be utilized to facilitate earlier abdominal fascial closure among those with open abdominal wounds
6. Use a protocol to try to avoid a positive cumulative fluid balance in the critically ill with, or at risk of, IAH

Statements not accepted as appropriate for pediatric care that were not supported for adult care

1. No recommendation was made regarding the use of the abdominal perfusion pressure as a resuscitation endpoint
2. No recommendation was made regarding the use of decompressive laparotomy for patients with severe IAH 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 among patients with open abdominal wounds
5. Use of enhanced ratios of plasma to packed red blood cells during resuscitation from massive hemorrhage
6. Efforts and/or protocols to obtain early or at least same-hospital-stay fascial closure

ACS abdominal compartment syndrome, IAP intra-abdominal pressure, IAH intra-abdominal hypertension

and pregnant patients have not yet been adequately defined, and the influence of IAH and ACS in these patients is somewhat poorly understood [91, 92]. Thus, further work among these patient populations is urgently needed. Finally, as overt ACS becomes less common [27], further research must be performed in order to delineate what role IAH without ACS plays in gut ischemia, bacterial translocation, feeding intolerance, anastomotic and wound breakdown, and neurological dysfunction [93–95].

The GRADE system was used to formulate the updated consensus management statements. GRADE is practical in requiring clinical judgements to be made in the context of weighing potential benefits and harms, the burdens of therapy both to the patient and society, and involved costs, with the overall assessment of the quality based on the entire body of evidence, rather than any particular study [96]. Therefore, in the context of making recommendations, the quality of evidence ultimately reflects the degree of confidence that a panel of expert clinicians has in the estimates of effect size [96]. The combined, collective experience is therefore reflected in the RECOMMENDATIONS and SUGGESTIONS, wherein the evidence is

reflected in the quality of evidence assessment. With this background, these guidelines should be used as guides for any institution or clinician to initiate their care of the critically ill, at all times evaluating the patients' outcomes ideally in a formal research study or at least in an organized fashion. However, these guidelines should not be used as performance measures or quality assurance criteria to censure any physician or institution.

In utilizing these guidelines, clinicians should be aware that there are ongoing developments in medical knowledge. The panelists made great efforts to review the literature broadly, and to be aware of ongoing research that could influence recommendations. However, the reviewers focused on completed peer-reviewed studies that were available in the public domain. Although some studies could have been missed, we feel it unlikely that the exclusion of the results of these studies would significantly alter our provided recommendations. Nonetheless, it is probable that new knowledge will require future revision of this work. Given the lack of high-quality evidence to base decision-making, this is desirable, and thus users are reminded to use these guidelines in the context of knowing their patients, acting at the bedside, and considering new data as it becomes available.

Acknowledgments Dr. Roberts is supported by an Alberta Innovates—Health Solutions Clinician Fellowship Award and funding from the Clinician Investigator Program at the University of Calgary. We thank Gordon Guyatt, MD, MSc, Department of Medicine, McMaster University, Hamilton, Ontario, Canada L8P 3B6, Department of Clinical Epidemiology and Biostatistics, McMaster University for methodological guidance. We also thank Ms. Michelle Mercado and Ms. Alma Rados of the Trauma Association of Canada for web-hosting and editing. This manuscript was commissioned and supported by the World Society of the Abdominal Compartment Syndrome (www.wsacs.org).

Conflicts of interest Andrew W Kirkpatrick has served on an advisory board for Lantheus Medical, Boston, MA, discussing the use of ultrasound contrast media. He received an unrestricted research grant from Kinetic Concepts Incorporated to conduct a prospective randomized trial in open abdomen management. He also received the unrestricted use of a Sonosite NanoMaxx ultrasound machine for research use from the Sonosite Corporation. Jan De Waele has consulted for Smith and Nephew, Ltd., Kinetic Concepts Incorporated, Pfizer and Astra Zenica Corporations. Roman Jaeschke served as a consultant on behalf of the GRADE group to the World Society of the Abdominal Compartment Syndrome. Manu Malbrain served on an Advisory Board for Pulsion Medical Systems, and has consulted for ConvaTec, Kinetic Concepts Incorporated, and Fresenius-Kabi. Martin Bjorck received an unrestricted research grant from Kinetic Concepts Incorporated in 2006. Michael Sugrue has received a speaking Honorarium from Kinetic Concepts Incorporated in 2009 and from Smith and Nephew, Ltd., in 2010–2011. Michael Cheatham has consulted for Kinetic Concepts Incorporated and has provided expert legal testimony concerning IAH and the abdominal compartment syndrome. Rao Ivatury has consulted for Kinetic Concepts Incorporated. Annika Reintam Blaser has consulted for Nestle Health Science. Mark Kaplan served as a consultant for Kinetic Concepts Incorporated. Edward Kimball has received remuneration for lecturing on the Abviser, manufactured by the Abviser Medical Company

and receives royalties from its use. No other authors had potential conflicts of interest to report.

Open Access This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and the source are credited. The exclusive right to any commercial use of the article is with Springer.

Appendix

Additional group authorship: the Pediatric Guidelines Sub-Committee

Chair, Janeth Chiaka Ejike, MD, FAAP, Department of Pediatrics, Loma Linda University Children's Hospital, Loma Linda, CA—No conflicts of interest.

Members

Michael Sasse, MD, Hanover Medical School, Department of Paediatric Cardiology and Intensive Care,

Germany, Contact +49-521-532 9041—Sasse, MD, received honorarium and travel fees from the Pall Corporation and B Braun Corporation. There were no conflicts of interest with the present work.

Torsten Kausen, MD, Hanover Medical School, Department of Paediatric Cardiology and Intensive Care, Germany, Contact +49-521-532 9041—Kauseen, MD, received travel fees from the B Braun Corporation. There were no conflicts of interest with the present work.

Don Moores, MD, Associate Professor of Surgery, Chief of Pediatric Surgery, Medical Director of Pediatric Trauma Services, Loma Linda University. Children's Hospital, Loma Linda, CA—No conflicts of interest.

Mudit Mathur, MD, FAAP, Department of Pediatrics, Loma Linda University Children's Hospital, Loma Linda, CA—No conflicts of interest.

Francisco J. Diaz Sotomayor, MD, Assistant Professor, Pediatrics, Pediatric Cardiology, Pediatric Critical Care Medicine, University Pediatric Hospital, University of Puerto Rico, San Juan, PR.

Rebecka Meyers, MD, Professor of Surgery, University of Utah, Salt Lake City, UT, United States of America—No conflicts of interest.

References

1. Balogh ZJ, Leppaniemi A (2009) The neglected (abdominal) compartment: what is new at the beginning of the 21st century? *World J Surg* 33:1109
2. Kimball EJ, Kim W, Cheatham ML, Malbrain ML (2007) Clinical awareness of intra-abdominal hypertension and abdominal compartment syndrome in 2007. *Acta Clin Belg (Suppl)*: 66–73
3. Malbrain ML, Cheatham ML, Kirkpatrick A, Sugrue M, Parr M, De Waele J, Balogh Z, Leppaniemi A, Olvera C, Ivatury R, D'Amours S, Wendon J, Hillman K, Johansson K, Kolkman K, Wilmer A (2006) Results from the international conference of experts on intra-abdominal hypertension and abdominal compartment syndrome. I. Definitions. *Intensive Care Med* 32:1722–1732
4. Malbrain ML, Cheatham ML (2011) Definitions and pathophysiological implications of intra-abdominal hypertension and abdominal compartment syndrome. *Am Surg* 77(Suppl 1):6–11
5. Cheatham ML, Malbrain ML, Kirkpatrick A, Sugrue M, Parr M, De Waele J, Balogh Z, Leppaniemi A, Olvera C, Ivatury R, D'Amours S, Wendon J, Hillman K, Wilmer A (2007) Results from the international conference of experts on intra-abdominal hypertension and abdominal compartment syndrome. II. Recommendations. *Intensive Care Med* 33:951–962
6. De Waele JJ, Cheatham ML, Malbrain ML, Kirkpatrick AW, Sugrue M, Balogh Z, Ivatury R, De Keulenaer B, Kimball EJ (2009) Recommendations for research from the international conference of experts on intra-abdominal hypertension and abdominal compartment syndrome. *Acta Clin Belg* 64:203–209
7. Holcomb JB, Jenkins D, Rhee P, Johannigman J, Mahoney P, Mehta S, Cox ED, Gehrke MJ, Beilman GJ, Schreiber M, Flaherty SF, Gratwohl KW, Spinella PC, Perkins JG, Beekley AC, McMullin NR, Park MS, Gonzalez EA, Wade CE, Dubick MA, Schwab CW, Moore FA, Champion HR, Hoyt DB, Hess JR (2007) Damage control resuscitation: directly addressing the early coagulopathy of trauma. *J Trauma* 62:307–310
8. Cotton BA, Reddy N, Hatch QM, LeFebvre E, Wade CE, Kozar RA, Gill BS, Albarado R, McNutt MK, Holcomb JB (2011) Damage control resuscitation is associated with a reduction in resuscitation volumes and improvement in survival in 390 damage control laparotomy patients. *Ann Surg* 254:598–605
9. Cotton BA, Au BK, Nunez TC, Gunter OL, Robertson AM, Young PP (2009) Predefined massive transfusion protocols are associated with a reduction in organ failure and post-injury complications. *J Trauma* 66:41–48 (discussion 48–49)
10. Duchesne JC, Barbeau JM, Islam TM, Wahl G, Greiffenstein P, McSwain NE Jr (2011) Damage control resuscitation: from emergency department to the operating room. *Am Surg* 77:201–206
11. Dzik WH, Blajchman MA, Fergusson D, Hameed M, Henry B, Kirkpatrick AW, Korogyi T, Logsetty S, Skeate RC, Stanworth S, Macadams C, Muirhead B (2011) Clinical review: Canadian National Advisory Committee on blood and blood products—massive transfusion consensus conference 2011: report of the panel. *Crit Care* 15:242

12. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E, Tomlanovich M (2001) Early goal-directed therapy in the treatment of severe sepsis and septic shock. *N Engl J Med* 345:1368–1377
13. Antonelli M, Bonten M, Cecconi M, Chastre J, Citerio G, Conti G, Curtis JR, Hedenstierna G, Joannidis M, Macrae D, Maggiore SM, Mancebo J, Mebazaa A, Preiser JC, Rocco P, Timsit JF, Wernerman J, Zhang H (2013) Year in review in intensive care medicine 2012. II: pneumonia and infection, sepsis, coagulation, hemodynamics, cardiovascular and microcirculation, critical care organization, imaging, ethics and legal issues. *Intensive Care Med* 39:345–364
14. Vincent JL, Sakr Y, Sprung CL, Ranieri VM, Reinhart K, Gerlach H, Moreno R, Carlet J, Le Gall JR, Payen D, Sepsis Occurrence in Acutely Ill Patients Investigators (2006) Sepsis in European intensive care units: results of the SOAP study. *Crit Care Med* 34:344–353
15. Cheatham ML, Safcsak K (2010) Is the evolving management of intra-abdominal hypertension and abdominal compartment syndrome improving survival? *Crit Care Med* 38:402–407
16. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schunemann HJ (2008) GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 336:924–926
17. Guyatt GH, Oxman AD, Kunz R, Vist GE, Falck-Ytter Y, Schunemann HJ (2008) What is “quality of evidence” and why is it important to clinicians? *BMJ* 336:995–998
18. Guyatt GH, Oxman AD, Kunz R, Falck-Ytter Y, Vist GE, Liberati A, Schunemann HJ (2008) Going from evidence to recommendations. *BMJ* 336:1049–1051
19. Jaeschke R, Guyatt GH, Dellinger P, Schunemann H, Levy MM, Kunz R, Norris S, Bion J (2008) Use of GRADE grid to reach decisions on clinical practice guidelines when consensus is elusive. *BMJ* 337:a744
20. Guyatt GH, Oxman AD, Sultan S, Glasziou P, Akl EA, Alonso-Coello P, Atkins D, Kunz R, Brozek J, Montori V, Jaeschke R, Rind D, Dahm P, Meerpohl J, Vist G, Berliner E, Norris S, Falck-Ytter Y, Murad MH, Schunemann HJ (2011) GRADE guidelines: 9. Rating up the quality of evidence. *J Clin Epidemiol* 64:1311–1316
21. Nunnally ME, Jaeschke R, Bellingan GJ, Lacroix J, Mourvillier B, Rodriguez-Vega GM, Rubertsson S, Vassilakopoulos T, Weinert C, Zanotti-Cavazzoni S, Buchman TG (2011) Targeted temperature management in critical care: a report and recommendations from five professional societies. *Crit Care Med* 39:1113–1125
22. Bates SM, Jaeschke R, Stevens SM, Goodacre S, Wells PS, Stevenson MD, Kearon C, Schunemann HJ, Crowther M, Pauker SG, Makdissi R, Guyatt GH (2012) Diagnosis of DVT: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of chest physicians evidence-based clinical practice guidelines. *Chest* 141:e351S–e418S
23. Guyatt GH, Oxman AD, Kunz R, Atkins D, Brozek J, Vist G, Alderson P, Glasziou P, Falck-Ytter Y, Schunemann HJ (2011) GRADE guidelines: 2. Framing the question and deciding on important outcomes. *J Clin Epidemiol* 64:395–400
24. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, Norris S, Falck-Ytter Y, Glasziou P, DeBeer H, Jaeschke R, Rind D, Meerpohl J, Dahm P, Schunemann HJ (2011) GRADE guidelines: 1. Introduction-GRADE evidence profiles and summary of findings tables. *J Clin Epidemiol* 64:383–394
25. Guyatt GH, Oxman AD, Schunemann HJ, Tugwell P, Knottnerus A (2011) GRADE guidelines: a new series of articles in the *Journal of Clinical Epidemiology*. *J Clin Epidemiol* 64:380–382
26. Guyatt GH, Oxman AD, Vist G, Kunz R, Brozek J, Alonso-Coello P, Montori V, Akl EA, Djulbegovic B, Falck-Ytter Y, Norris SL, Williams JW Jr, Atkins D, Meerpohl J, Schunemann HJ (2011) GRADE guidelines: 4. Rating the quality of evidence—study limitations (risk of bias). *J Clin Epidemiol* 64:407–415
27. Balogh ZJ, Martin A, van Wessem KP, King KL, Mackay P, Havill K (2011) Mission to eliminate postinjury abdominal compartment syndrome. *Arch Surg* 146:938–943
28. Reintam Blaser A, Parm P, Kitus R, Starkopf J (2011) Risk factors for intra-abdominal hypertension in mechanically ventilated patients. *Acta Anaesthesiol Scand* 55:607–614
29. Dalfino L, Tullo L, Donadio I, Malcangi V, Brienza N (2008) Intra-abdominal hypertension and acute renal failure in critically ill patients. *Intensive Care Med* 34:707–713
30. Balogh Z, McKinley BA, Holcomb JB, Miller CC, Cocanour CS, Kozar RA, Valdivia A, Ware DN, Moore FA (2003) Both primary and secondary abdominal compartment syndrome can be predicted early and are harbingers of multiple organ failure. *J Trauma* 54:848–859 (discussion 859–861)
31. Madigan MC, Kemp CD, Johnson JC, Cotton BA (2008) Secondary abdominal compartment syndrome after severe extremity injury: are early, aggressive fluid resuscitation strategies to blame? *J Trauma* 64:280–285
32. Kirkpatrick AW, Pelosi P, De Waele JJ, Malbrain ML, Ball CG, Meade MO, Stelfox HT, Laupland KB (2010) Clinical review: intra-abdominal hypertension: does it influence the physiology of prone ventilation? *Crit Care* 14:232
33. Hering R, Vorwerk R, Wrigge H, Zinserling J, Schroder S, von Spiegel T, Hoeft A, Putensen C (2002) Prone positioning, systemic hemodynamics, hepatic indocyanine green kinetics, and gastric intramucosal energy balance in patients with acute lung injury. *Intensive Care Med* 28:53–58
34. Hering R, Wrigge H, Vorwerk R, Brensing KA, Schroder S, Zinserling J, Hoeft A, Spiegel TV, Putensen C (2001) The effects of prone positioning on intraabdominal pressure and cardiovascular and renal function in patients with acute lung injury. *Anesth Analg* 92:1226–1231
35. Vidal MG, Ruiz Weisser J, Gonzalez F, Toro MA, Loudet C, Balasini C, Canales H, Reina R, Estenssoro E (2008) Incidence and clinical effects of intra-abdominal hypertension in critically ill patients. *Crit Care Med* 36:1823–1831
36. Ke L, Ni HB, Sun JK, Tong ZH, Li WQ, Li N, Li JS (2012) Risk factors and outcome of intra-abdominal hypertension in patients with severe acute pancreatitis. *World J Surg* 36:171–178
37. Kim IB, Prowle J, Baldwin I, Bellomo R (2012) Incidence, risk factors and outcome associations of intra-abdominal hypertension in critically ill patients. *Anaesth Intensive Care* 40:79–89
38. Malbrain ML, Chiumello D, Pelosi P, Bihari D, Innes R, Ranieri VM, Del Turco M, Wilmer A, Brienza N, Malcangi V, Cohen J, Japiassu A, Keulenaer BL, Daelemans R, Jacquet L, Laterre PF, Frank G, de Souza P, Cesana B, Gattinoni L (2005) Incidence and prognosis of intraabdominal hypertension in a mixed population of critically ill patients: a multi-center epidemiological study. *Crit Care Med* 33:315–322

39. De Keulenaer BL, Regli A, Dabrowski W, Kaloiani V, Bodnar Z, Cea JJ, Litvin AA, Davis WA, Palermo AM, De Waele JJ, Malbrain ML (2011) Does femoral venous pressure measurement correlate well with intrabdominal pressure measurement? A multicenter observational trial. *Intensive Care Med* 37:1620–1627
40. Cheatham ML, De Waele JJ, De Laet I, De Keulenaer B, Widder S, Kirkpatrick AW, Cresswell AB, Malbrain M, Bodnar Z, Mejia-Mantilla JH, Reis R, Parr M, Schulze R, Puig S (2009) The impact of body position on intra-abdominal pressure measurement: a multicenter analysis. *Crit Care Med* 37:2187–2190
41. Yi M, Leng Y, Bai Y, Yao G, Zhu X (2012) The evaluation of the effect of body positioning on intra-abdominal pressure measurement and the effect of intra-abdominal pressure at different body positioning on organ function and prognosis in critically ill patients. *J Crit Care* 27(222):e221–e226
42. McBeth PB, Zygun DA, Widder S, Cheatham M, Zengerink I, Glowa J, Kirkpatrick AW (2007) Effect of patient positioning on intra-abdominal pressure monitoring. *Am J Surg* 193:644–647 (discussion 647)
43. Bjorck M, D'Amours SK, Hamilton AE (2011) Closure of the open abdomen. *Am Surg* 77(Suppl 1):S58–S61
44. Kirkpatrick AW, Brenneman FD, McLean RF, Rapanos T, Boulanger BR (2000) Is clinical examination an accurate indicator of raised intra-abdominal pressure in critically injured patients. *Can J Surg* 43:207–211
45. Malbrain ML (2004) Different techniques to measure intra-abdominal pressure (IAP): time for a critical re-appraisal. *Intensive Care Med* 30:357–371
46. Cheatham ML, White MW, Sagraves SG, Johnson JL, Block EFJ (2000) Abdominal perfusion pressure: a superior parameter in the assessment of intra-abdominal hypertension. *J Trauma* 49:621–627
47. Ouellet JF, Leppaniemi A, Ball CG, Cheatham ML, D'Amours S, Kirkpatrick AW (2011) Alternatives to formal abdominal decompression. *Am Surg* 77(Suppl 1):S51–S57
48. De Keulenaer BL, De Waele JJ, Malbrain ML (2011) Nonoperative management of intra-abdominal hypertension and abdominal compartment syndrome: evolving concepts. *Am Surg* 77(Suppl 1):S34–S41
49. Cheatham ML (2009) Nonoperative management of intraabdominal hypertension and abdominal compartment syndrome. *World J Surg* 33:1116–1122
50. Deeren DH, Dits H, Malbrain ML (2005) Correlation between intra-abdominal and intracranial pressure in nontraumatic brain injury. *Intensive care medicine* 31:1577–1581
51. De Waele JJ, De Laet I, De Keulenaer B, Widder S, Kirkpatrick AW, Cresswell AB, Malbrain M, Bodnar Z, Mejia-Mantilla JH, Reis R, Parr M, Schulze R, Compano S, Cheatham M (2008) The effect of different reference transducer positions on intra-abdominal pressure measurement: a multicenter analysis. *Intensive Care Med* 34:1299–1303
52. Bauer JJ, Gelernt IM, Salky BA, Kreef I (1985) Is routine postoperative nasogastric decompression really necessary? *Ann Surg* 201:233–236
53. Pearl ML, Valea FA, Fischer M, Chalas E (1996) A randomized controlled trial of postoperative nasogastric tube decompression in gynecologic oncology patients undergoing intra-abdominal surgery. *Obstet Gynecol* 88:399–402
54. Peppriell JE, Bacon DR (2000) Acute abdominal compartment syndrome with pulseless electrical activity during colonoscopy with conscious sedation. *J Clin Anesth* 12:216–219
55. Quyn AJ, Johnston C, Hall D, Chambers A, Arapova N, Ogston S, Amin AI (2012) The open abdomen and temporary abdominal closure systems—historical evolution and systematic review. *Colorectal Dis* 14:e429–e438
56. Souadka A, Mohsine R, Ifrine L, Belkouchi A, El Malki HO (2012) Acute abdominal compartment syndrome complicating a colonoscopic perforation: a case report. *J Med Case Rep* 6:51
57. Ponc RJ, Saunders MD, Kimmey MB (1999) Neostigmine for the treatment of acute colonic pseudo-obstruction. *N Engl J Med* 341:137–141
58. Malbrain MLNG, Cordemans C, Van Regenmortel N (2012) Fluid overload is not only of cosmetic concern (Part II): results from a meta-analysis and practical approach. *ICU Manag* 2:34–41
59. Cordemans C, De Laet I, Van Regenmortel N, Schoonheydt K, Dits H, Huber W, Malbrain ML (2012) Fluid management in critically ill patients: the role of extravascular lung water, abdominal hypertension, capillary leak, and fluid balance. *Ann Intensive Care* 2(Suppl 1):S1
60. Cordemans C, De Laet I, Van Regenmortel N, Schoonheydt K, Dits H, Martin G, Huber W, Malbrain ML (2012) Aiming for a negative fluid balance in patients with acute lung injury and increased intra-abdominal pressure: a pilot study looking at the effects of PAL-treatment. *Ann Intensive Care* 2(Suppl 1):S15
61. Beekley AC (2008) Damage control resuscitation: a sensible approach to the exsanguinating surgical patient. *Critical Care Med* 36:S267–S274
62. Corcos AC, Sherman HF (2001) Percutaneous treatment of secondary abdominal compartment syndrome. *J Trauma* 51:1062–1064
63. Kirkpatrick AW, Ball CG, D'Amours SK, Zygun D (2008) Acute resuscitation of the unstable adult trauma patient: bedside diagnosis and therapy. *Can J Surg* 51:57–69
64. Sugrue M, D'Amours SK, Joshipura M (2004) Damage control surgery and the abdomen. *Injury* 35:642–648
65. De Waele J, Desender L, De Laet I, Ceelen W, Pattyn P, Hoste E (2010) Abdominal decompression for abdominal compartment syndrome in critically ill patients: a retrospective study. *Acta Clin Belg* 65:399–403
66. De Waele JJ, Hoste EA, Malbrain ML (2006) Decompressive laparotomy for abdominal compartment syndrome—a critical analysis. *Crit Care* 10:R51
67. Rotondo MF, Schwab CW, McGonigal MD, Phillips III GR, Fruchterman TM, Kauder DR, Latenser BA, Angood PA (1993) 'Damage control': an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma* 35:375–382 (discussion 382–373)
68. Cirocchi R, Abraha I, Montedori A, Farinella E, Bonacini I, Tagliabue L, Sciannameo F, (2010) Damage control surgery for abdominal trauma. *Cochrane Database Syst Rev*: CD007438
69. Johnson JW, Gracias VH, Schwab CW, Reilly PM, Kauder DR, Shapiro MB, Dabrowski P, Rotondo MF (2001) Evolution in damage control for exsanguinating penetrating abdominal injury. *J Trauma* 51:261–271
70. Finlay IG, Edwards TJ, Lambert AW (2004) Damage control laparotomy. *Br J Surg* 91:83–85
71. Stawicki SP, Brooks A, Bilski T, Scaff D, Gupta R, Schwab CW, Gracias VH (2008) The concept of damage control: extending the paradigm to emergency general surgery. *Injury* 39:93–101
72. Chow AW, Evans GA, Nathens AB, Ball CG, Hansen G, Harding GK, Kirkpatrick AW, Weiss K, Zhanel GG (2010) Canadian practice guidelines for surgical intra-abdominal infections. *Can J Infect Dis Med Microbiol* 21:11–37

73. Marshall JC, Innes M (2003) Intensive care unit management of intra-abdominal infection. *Crit Care Med* 31:2228–2237
74. Ball CG, Kirkpatrick AW, McBeth P (2008) The secondary abdominal compartment syndrome: not just another post-traumatic complication. *Can J Surg* 51:399–405
75. Boele van Hensbroek P, Wind J, Dijkgraaf MG, Busch OR, Carel Goslings J (2009) Temporary closure of the open abdomen: a systematic review on delayed primary fascial closure in patients with an open abdomen. *World J Surg* 33:199–207
76. Regner JL, Kobayashi L, Coimbra R (2012) Surgical strategies for management of the open abdomen. *World J Surg* 6:497–510
77. Acosta S, Bjarnason T, Petersson U, Palsson B, Wanhainen A, Svensson M, Djavani K, Bjorck M (2011) Multicentre prospective study of fascial closure rate after open abdomen with vacuum and mesh-mediated fascial traction. *Br J Surg* 98:735–743
78. Diaz JJ Jr, Dutton WD, Ott MM, Cullinane DC, Alouidor R, Armen SB, Bilanuik JW, Collier BR, Gunter OL, Jawa R, Jerome R, Kerwin AJ, Kirby JP, Lambert AL, Riordan WP, Wohltmann CD (2011) Eastern Association for the Surgery of Trauma: a review of the management of the open abdomen—part 2 “Management of the open abdomen”. *J Trauma* 71:502–512
79. Miller PR, Thompson JT, Faler BJ, Meredith JW, Chang MC (2002) Late fascial closure in lieu of ventral hernia: the next step in open abdomen management. *J Trauma* 53:843–849
80. Miller PR, Meredith JW, Johnson JC, Chang MC (2004) Prospective evaluation of vacuum-assisted fascial closure after open abdomen: planned ventral hernia rate is substantially reduced. *Ann Surg* 239:608–616
81. Batacchi S, Matano S, Nella A, Zagli G, Bonizzoli M, Pasquini A, Anichini V, Tucci V, Manca G, Ban K, Valeri A, Peris A (2009) Vacuum-assisted closure device enhances recovery of critically ill patients following emergency surgical procedures. *Crit Care* 13:R194
82. Kubiak BD, Albert SP, Gatto LA, Snyder KP, Maier KG, Vieau CJ, Roy S, Nieman GF (2010) Peritoneal negative pressure therapy prevents multiple organ injury in a chronic porcine sepsis and ischemia/reperfusion model. *Shock* 34:525–534
83. Rao M, Burke D, Finan PJ, Sagar PM (2007) The use of vacuum-assisted closure of abdominal wounds: a word of caution. *Colorectal Dis* 9:266–268
84. Ouellet JF, Ball CG (2011) Recurrent abdominal compartment syndrome induced by high negative pressure abdominal closure dressing. *J Trauma* 71:785–786
85. Roberts DJ, Zygun DA, Grendar J, Ball CG, Robertson HL, Ouellet JF, Cheatham ML, Kirkpatrick AW (2012) Negative-pressure wound therapy for critically ill adults with open abdominal wounds: a systematic review. *J Trauma Acute Care Surg* 73:629–639
86. El-Hayek KM, Chand B (2010) Biologic prosthetic materials for hernia repairs. *J Long Term Eff Med Implant* 20:159–169
87. Bachman S, Ramshaw B, (2008) Prosthetic material in ventral hernia repair: how do I choose? *Surg Clin North Am* 88:101–112 (ix)
88. Harth KC, Broome AM, Jacobs MR, Blatnik JA, Zeinali F, Bajaksouzian S, Rosen MJ (2011) Bacterial clearance of biologic grafts used in hernia repair: an experimental study. *Surg Endosc* 25:2224–2229
89. Scott BG, Welsh FJ, Pham HQ, Carrick MM, Liscum KR, Granchi TS, Wall MJ Jr, Mattox KL, Hirshberg A (2006) Early aggressive closure of the open abdomen. *J Trauma* 60:17–22
90. de Moya MA, Dunham M, Inaba K, Bahouth H, Alam HB, Sultan B, Namias N (2008) Long-term outcome of acellular dermal matrix when used for large traumatic open abdomen. *J Trauma* 65:349–353
91. Chun R, Baghirzada L, Tiruta C, Kirkpatrick AW (2012) Measurement of intra-abdominal pressure in term pregnancy: a pilot study. *Int J Obstet Anesth* 21:135–139
92. De Keulenaer BL, De Waele JJ, Powell B, Malbrain ML (2009) What is normal intra-abdominal pressure and how is it affected by positioning, body mass and positive end-expiratory pressure? *Intensive Care Med* 35:969–976
93. Diebel LN, Dulchavsky SA, Brown WJ (1997) Splanchnic ischemia and bacterial translocation in the abdominal compartment syndrome. *J Trauma* 43:852–855
94. Diebel L, Saxe J, Dulchavsky S, (1992) Effect of intra-abdominal pressure on abdominal wall blood flow. *Am Surg* 58:573–575 (discussion 575–576)
95. Antonelli M, Bonten M, Cecconi M, Chastre J, Citerio G, Conti G, Curtis JR, Hedenstierna G, Joannidis M, Macrae D, Maggiore SM, Mancebo J, Mebazaa A, Preiser JC, Rocco P, Timsit JF, Wernerman J, Zhang H (2013) Year in review in intensive care medicine 2012: I. Neurology and neurointensive care, epidemiology and nephrology, biomarkers and inflammation, nutrition, experimentals. *Intensive Care Med* 39:232–246
96. Balshem H, Helfand M, Schunemann HJ, Oxman AD, Kunz R, Brozek J, Vist GE, Falck-Ytter Y, Meerpohl J, Norris S, Guyatt GH (2011) GRADE guidelines: 3. Rating the quality of evidence. *J Clin Epidemiol* 64:401–406
97. Bjorck M, Bruhin A, Cheatham M, Hinck D, Kaplan M, Manca G, Wild T, Windsor A (2009) Classification—important step to improve management of patients with an open abdomen. *World J Surg* 33:1154–1157