Michael F. Rotondo MD FACS
Professor and Chairman – Department of Surgery
The Brody School of Medicine – East Carolina University
Chief of Surgery – Vidant Medical Center
Chair of the Committee on Trauma for the American College of Surgeons

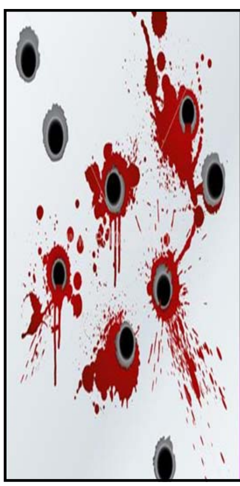
DAMAGE CONTROL:

REVOLUTION-REJUVENATION-RECAPITULATION

LEAVE IT OPEN – WHERE DID THIS RIDICULOUS IDEA COME FROM

A total or radical change; a revolution in one's circumstances or way of living. A drastic and far-reaching change in ways of thinking and behaving

REVOLUTION



9MM SEMI-AUTOMATIC WEAPONRY

The Milieu for Revolution

- Trauma System Development
- Trauma Center Development
- The Singular Focus of Surgeons
- The Increase in Violence in Urban America

… the only missing element was frustration …

Abdominal Gunshot Wounds
300 Consecutive Patients

- 88.3% survival
- Major Vascular Injuries
  - 82.8% deaths
  - 60% overall survival

1988 J. Trauma - Feliciano et.al.

Principles

- Large volume resuscitation with isotonic crystalloids (3:1)
- Extracellular fluid redistributes during shock into both intravascular and intracellular spaces
- Optimal resuscitation corrects the extra-cellular deficit

....dogma that has stood unchallenged for over 40 years...

Hypothermia

Dilution

Coagulopathy

Metabolic Acidosis

The Triangle of Death

Damage Control ...

PART I – OR
- control of hemorrhage
- control of contamination
- abbreviation/packing
- temporary closure

PART II – ICU
- restoration of physiology

PART III – OR
- definitive reconstruction

Rotondo et al, Journal of Trauma 1993

Cumulative Review

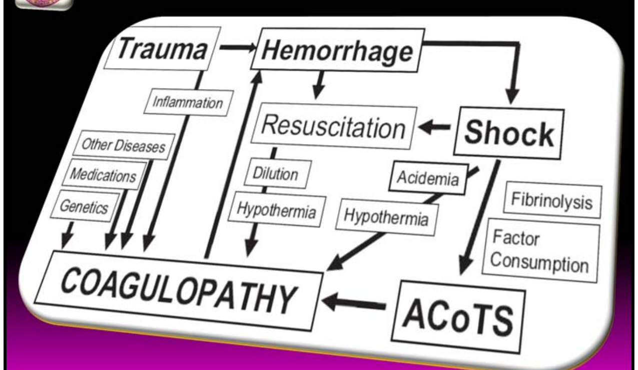
Damage Control - 1976 to 2004

Injury	N	Mortality (%)	Morbidity (%)
Hepatic	728	39	38
Multiple	833	42	44
TOTAL	*1561*	*40*	*41*

**unpublished cumulative review*

The phenomenon of vitality and freshness being restored.

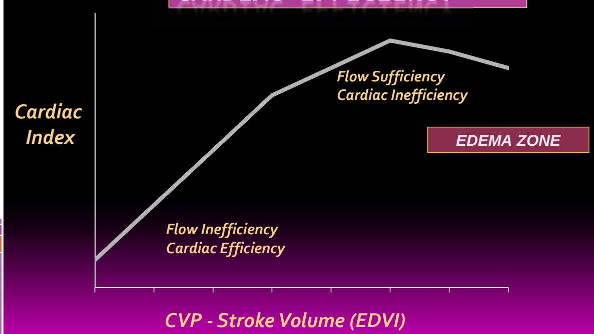
REJUVENATION



Other Technical Breaks

- The use of temporary intravascular shunts
- Avoidance of enterostomy tubes
- Avoidance of stomas
- Delay of definitive GI reconstruction
- Judicious use of the planned ventral hernia

HEMODYNAMICS
CARDIAC EFFICIENCY

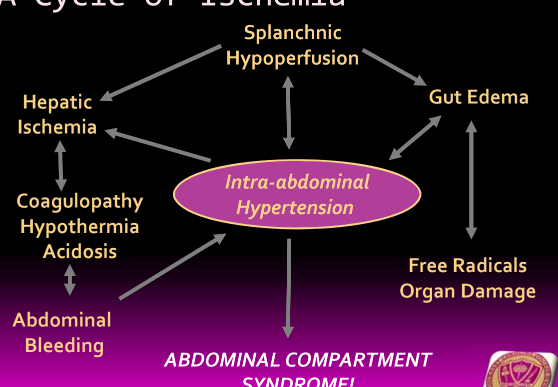


Intra-abdominal Hypertension

- Markedly increased intra-abdominal pressure
- Pressure-related regional blood flow disturbances culminating in end organ dysfunction and failure
- Elevated IAP + systemic signs/symptoms :

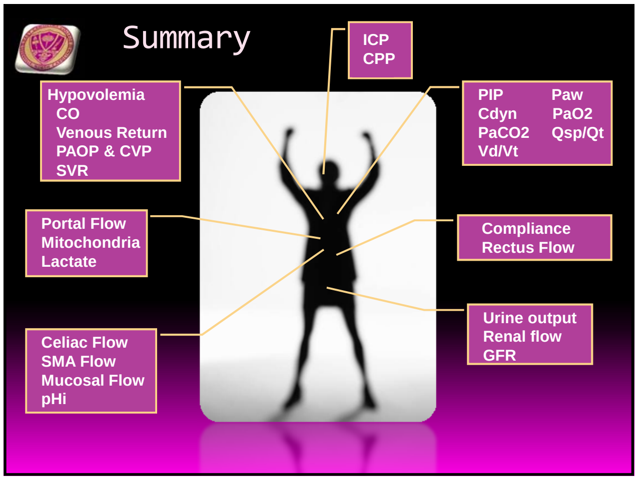
Abdominal Compartment Syndrome

A Cycle of Ischemia



*Ivatury 1995

Summary



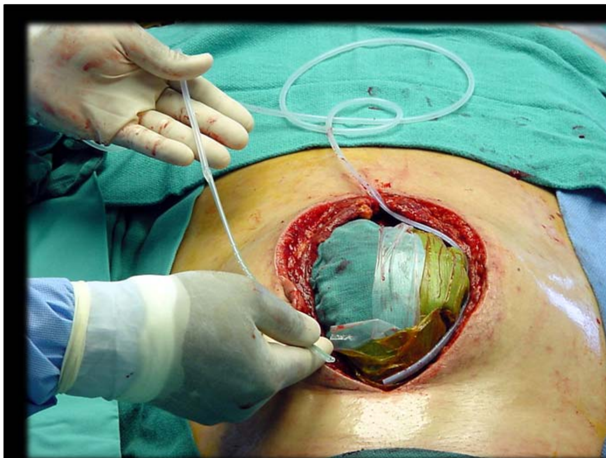
The Management of the Open Abdomen in Trauma and Emergency General Surgery: Part 1—Damage Control

Jose J. Diaz, Jr., MD, Daniel C. Cullinane, MD, William D. Dutton, MD, Rebecca Jerome, MS, Richard Bagdonas, MD, Jarolslaw O. Bilaniuk, MD, Bryan R. Collier, DO, John J. Como, MD, John Cumming, MD, Maggie Griffen, MD, Oliver L. Gunter, MD, John Kirby, MD, Larry Lottenburg, MD, Nathan Mowery, MD, William P. Riordan, Jr., MD, Niels Martin, MD, Jon Platz, MD, Nicole Stassen, MD, and Eleanor S. Winston, MD

*The Journal of **TRAUMA® Injury, Infection, and Critical Care • Volume 68, Number 6, June 2010***

Grade	*Bladder Pressure (mmHg)*	*Treatment*
I	10-15	*normovolemic*
II	15-25	*hypervolemic*
III	25-35	*ICU Open*
IV	>35	*OR Open*

Burch - Surgical Clinics of North America 76:833, 1996



VAC Dressings

(music) the repetition of themes introduced earlier (especially when one is composing the final part of a movement)

RECAPITULATION

Abdominal Complications Damage Control

Complication	Frequency (%)
Abscess/Collection	24
Wound Infection/Dehisc.	8.2
Bile Leak	3.7
Fistula	2.4
Intestinal Necrosis	1.5

… a review of 193 complications in 461 patients …

Damage Control – Is the frustration mounting?

THE BEGINNING OF THE END

Journal of Trauma: July 2010 - Volume 69 - Issue 1 - pp 53-59

Damage Control Laparotomy: A Vital Tool Once Overused

Higa, Guillermo MD; Friese, Randall MD; O'Keeffe, Terence MD, MSPH; Wynne, Julie MD; Bowlby, Paul RN; Ziemba, Michelle RN; Latifi, Rifat MD; Kulvatunyou, Narong MD; Rhee, Peter MD, MPH

DAMAGE CONTROL

How did we get here?

- Inaccurate Endpoints
- Crystalloid Myths
- Transfusion Confusion
- Inflammatory Fugue

Era	Focus	Resuscitation	Outcome
World War I	Wound Toxins	None	Early Death
World War II, Korean War	Intravascular Repletion	Colloids, Blood	– Early survival ARF → Death
Vietnam War	Intravascular and Extra-cellular Repletion	Crystalloids, Banked Blood	– Early survival ↓ARF ARDS → Death
1970s-80s	ICUs, Organ Failure, Metabolic Support	PA catheters, Resuscitation Endpoints	↓ARF, ARDS ↑ MOF deaths
Mid-1980s to Present	Trauma Centers and Systems	Rapid Triage, Damage Control, ICUs	– Early survival ↓ ARDS, MOF ↓ Related Death

Moore, FA, et al. The Next Generation in Shock Resuscitation. The Lancet 2004; 363: 1988-1996.

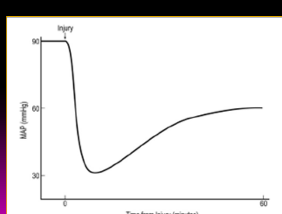
Leaky Buckets

"The purpose of models is not to fit the data but to sharpen the questions."
Samuel Karlin 1983

From "Leaky Buckets" to Vascular Injuries: Understanding Models of Uncontrolled Hemorrhage

Asher Hirshberg, MD, FACS, David B Hoyt, MD, FACS, Kenneth L Mattox, MD, FACS

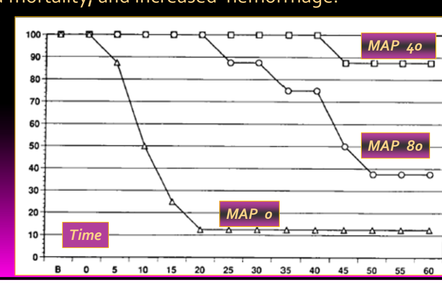
- Three major processes not fully understood:
  - Pressure-driven bleeding
  - Intrinsic hemostasis
  - Fluid resuscitation
    - *JACS 2007*



IMPROVED OUTCOME WITH HYPOTENSIVE RESUSCITATION OF UNCONTROLLED HEMORRHAGIC SHOCK IN A SWINE MODEL

Terry Kowalenko, MD, Susan Stern, MD, Steven Dronen, MD, and Xu Wang, MD

- Saline infusion to maintain MAP in pigs; MAP of 40, 80, & 0 with survival rate 87.5%, 37.5% & 12%; attempts to normalize BP increased mortality, and increased hemorrhage.
  - *J Trauma 1992*



Immediate versus Delayed Fluid Resuscitation for Hypotensive Patients with Penetrating Torso Injuries
William H. Bickell, Matthew J. Wall, Paul E. Pepe, R. Russell Martin, Victoria F. Ginger, Mary K. Allen, and Kenneth L. Mattox

- Penetrating torso: 70% survival rate in delayed resuscitation
  - Bickell 1994 –

"…aggressive administration of intravenous fluids to hypotensive patients with penetrating injuries to the torso should be delayed…"

NEJM 1994

Permissive Hypotension

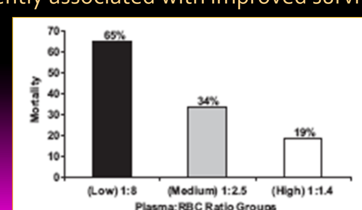
- Cannon proposed it in 1918: WWI
  - "Injection of fluid that will increase BP has dangers in and of itself."
- "Popping the clot" at SBP 80
  - Kowalenko 1992 - Bickell 1994
  - Dutton 2002 - Turner 2000
  - Owens 1995
- Penetrating torso: 70% survival rate in delayed resuscitation
  - Bickell 1994 - Tisherman 2000
- Abdominal aortic aneurysms standard of care to prevent re-bleed; SBP 70-85
  - Crawford 1991
- US Military 1998: permissive hypotension preferred treatment
  - Loss of consciousness - give fluid to regain mental status or SBP 70
    - *Office of Naval Research 2001/2002 Consensus*

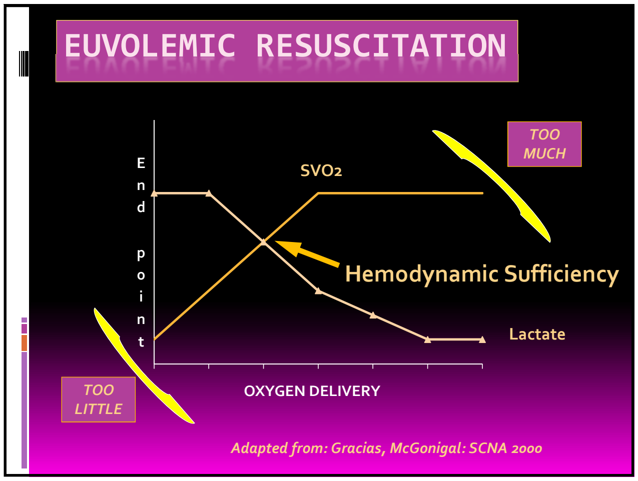
Damage Control Resuscitation

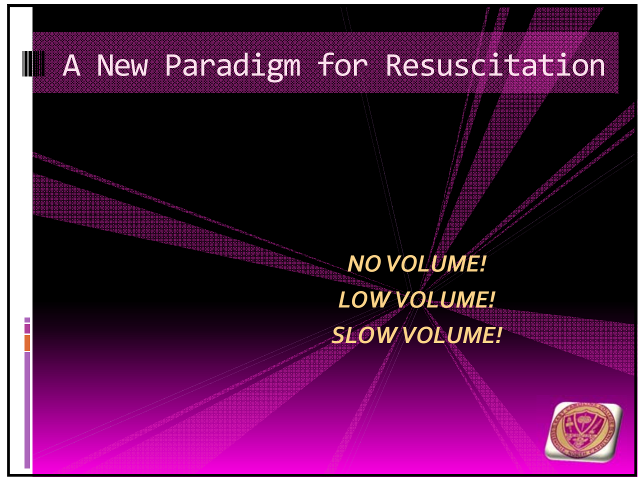
- Dubick and Atkins, J Trauma 2003
  - Concept Paper
  - Small Volume Resuscitation
  - Permissive Hypotension
  - Hypertonic Saline Dextran
- Holcomb *et al*, J Trauma 2005
  - Manual vital signs – radial pulse
  - GCS: motor and verbal
  - Non-head injured patients

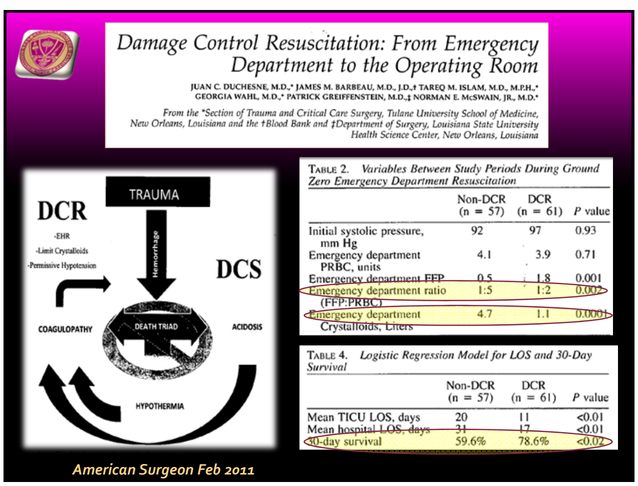
The Ratio of Blood Products Transfused Affects Mortality in Patients Receiving Massive Transfusions at a Combat Support Hospital
Matthew A. Borgman, MD, Philip C. Spinella, MD, Jeremy G. Perkins, MD, Kurt W. Grathwohl, MD, Thomas Repine, MD, Alec C. Beekley, MD, James Sebesta, MD, Donald Jenkins, MD, Charles E. Wade, PhD, and John B. Holcomb, MD

- Retrospective Operation Iraqi Freedom Operation: 1:1.4 ratio (Plasma:PRBC) independently associated with improved survival
  - *J Trauma 2007*









Damage Control Resuscitation: From Emergency Department to the Operating Room

JUAN C. DUCHESNE, M.D.,* JAMES M. BARBEAU, M.D., J.D.,† TAREQ M. ISLAM, M.D., M.P.H.,* GEORGIA WAHL, M.D.,* PATRICK GREIFFENSTEIN, M.D.,‡ NORMAN E. McSWAIN, JR., M.D.*

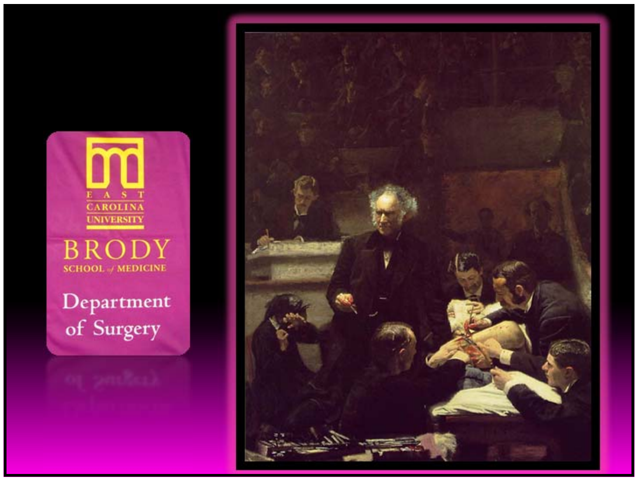
*From the *Section of Trauma and Critical Care Surgery, Tulane University School of Medicine, New Orleans, Louisiana and the †Blood Bank and ‡Department of Surgery, Louisiana State University Health Science Center, New Orleans, Louisiana*

TABLE 2. *Variables Between Study Periods During Ground Zero Emergency Department Resuscitation*

	Non-DCR (n = 57)	DCR (n = 61)	P value
Initial systolic pressure, mm Hg	92	97	0.93
Emergency department PRBC, units	4.1	3.9	0.71
Emergency department FFP	0.5	1.8	0.001
Emergency department ratio (FFP:PRBC)	1:5	1:2	0.002
Emergency department Crystalloids, Liters	4.7	1.1	0.0001

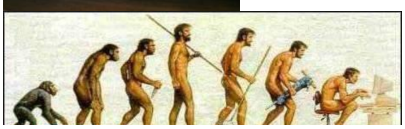
TABLE 4. *Logistic Regression Model for LOS and 30-Day Survival*

	Non-DCR (n = 57)	DCR (n = 61)	P value
Mean TICU LOS, days	20	11	<0.01
Mean hospital LOS, days	31	17	<0.01
30-day survival	59.6%	78.6%	<0.02

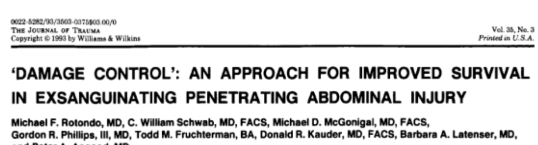

EAST
CAROLINA
UNIVERSITY
BRODY
SCHOOL of MEDICINE
Department
of Surgery

THE UNIVERSITY OF ARIZONA
MEDICAL CENTER
Trauma Services

Damage
Control
Laparotomy
Peter Rhee MD



- Pringle - 1908
- Stone - 1983
- Rotondo - 1993



0022-5282/93/3503-0375$03.00/0
THE JOURNAL OF TRAUMA
Copyright © 1993 by Williams & Wilkins
Vol. 35, No. 3
Printed in U.S.A.

'DAMAGE CONTROL': AN APPROACH FOR IMPROVED SURVIVAL IN EXSANGUINATING PENETRATING ABDOMINAL INJURY

Michael F. Rotondo, MD, C. William Schwab, MD, FACS, Michael D. McGonigal, MD, FACS, Gordon R. Phillips, III, MD, Todd M. Fruchterman, BA, Donald R. Kauder, MD, FACS, Barbara A. Latenser, MD, and Peter A. Angood, MD

Table 1
Demographic data, injury scoring, and survivorship for the definitive laparotomy (DL) and damage control (DC) patients in the overall group (n = 46)

	DL (n = 22)	DC (n = 24)
Age (years)	31.5 ± 12.3	30.6 ± 9.6
Sex (M:F)	22:0	23:1
Mechanism of Injury (GSW:SW)	18:4	19:5
RTS	6.44 ± 2.1	6.11 ± 2.2
ISS	22.9 ± 8.7	24.2 ± 7.7
Ps	0.835 ± 0.292	0.781 ± 0.302
PATI	29.8 ± 15.7	37.8 ± 13.9
Actual Survival	12 (55%)	14 (58%)

Reported as mean ± standard deviation.

Table 6
Injury scoring and survivorship for patients with one or more major vascular injury and two or more visceral injuries—the maximum injury subset (n = 22)

	DLM (n = 9)	DCM (n = 13)
RTS	5.29 ± 2.8	6.22 ± 2.6
ISS	23.8 ± 10.8	22.9 ± 6.2
Ps	0.670 ± 0.396	0.810 ± 0.295
PATI	40.9 ± 12.4	43.0 ± 11.0
Actual Survival	1 (11%)	10 (77%)

Reported as mean ± standard deviation.
* Fisher's exact test, $p < 0.02$.

REVIEW ARTICLE

The Journal of TRAUMA® *Injury, Infection, and Critical Care*

Damage Control: Collective Review

Michael B. Shapiro, MD, Donald H. Jenkins, MD, C. William Schwab, MD, and Michael F. Rotondo, MD

J Trauma 2000;49:969–978.

The Journal of TRAUMA® *Injury, Infection, and Critical Care*

Table 1 Cumulative Review of Damage Control

Year	Author	N	Mortality	% Mortality	Morbidity	% Morbidity
1976	Lucas	3	0/3	0	—	—
1979	Caine	4	0/4	0	—	—
1981	Feliciano	10	1/10	10	6/9	67
1982	Svoboda	12	2/12	17	—	—
1983	Stone	17	6/17	35	11/11	100
1984	Carmona	17	2/17	12	5/15	33
1985	Baracco	36	6/36	17	4/36	11
1986	Ivatury	14	8/14	57	5/6	83
1986	Feliciano	66	38/66	58	9/49	19
1988	Cogbill	52	31/52	60	3/21	14
1990	Saifi	9	2/9	22	6/9	67
1990	Beal	49	19/49	39	7/30	23
1990	Aprahamian	20	4/20	20	9/16	56
1990	Cue	35	17/35	49	19/21	90
1992	Krige	22	6/22	27	12/16	75
1992	Burch	200	134/200	67	38/86	44
1992	Sharp	39	17/39	44	6/22	27
1992	Shen	6	3/6	50	—	—
1992	Talbert	11	4/11	36	3/7	43
1993	Carillo	14	2/14	14	9/12	75
1993	Rotondo	24	10/24	42	5/14	36
1993	Morris	107	64/107	60	22/43	51
1994	Hirshberg	124	72/124	58	—	—
1996	Garrison	70	47/70	67	6/38	16
1996	Richardson	21	8/21	38	—	—
1997	Ivatury	1	0/1	0	0/1	0
1997	Porter	1	0/1	0	0/1	0
1997	Shaftan	5	0/5	0	2/5	40
1997	Carillo	3	0/3	0	2/3	67
1998	Chang	6	0/6	0	6/6	100
1998	Demetriades	3	0/3	0	0/3	0
Total		1,001	593/1,001	59	193/480	40

Adapted with permission from Rotondo MF, Zonies DH. The damage control sequence and underlying logic. *Surg Clin North Am.* 1997;77:761–777.

The Journal of TRAUMA® *Injury, Infection, and Critical Care*

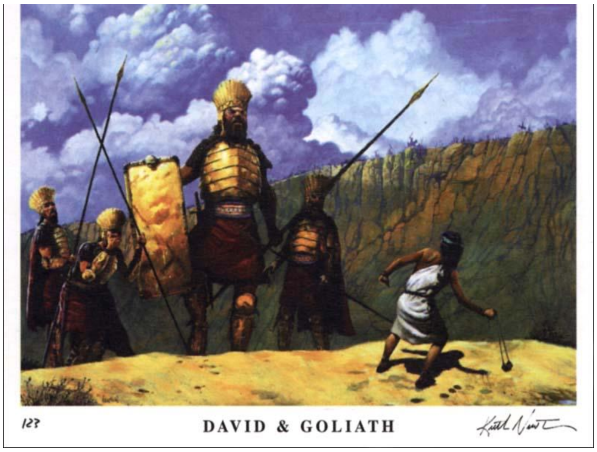
Long Term Impact of Damage Control Surgery: A Preliminary Prospective Study

Erica Sutton, MD, Grant V. Bochicchio, MD, MPH, Kelly Bochicchio, RN, MS, Eduardo D. Rodriguez, MD, Sharon Henry, MD, Manjari Joshi, MD, and Thomas M. Scalea, MD

Conclusion: **Although damage control laparotomy is associated with a significant complication and readmission rate, its long term survival and benefit is indisputable.**

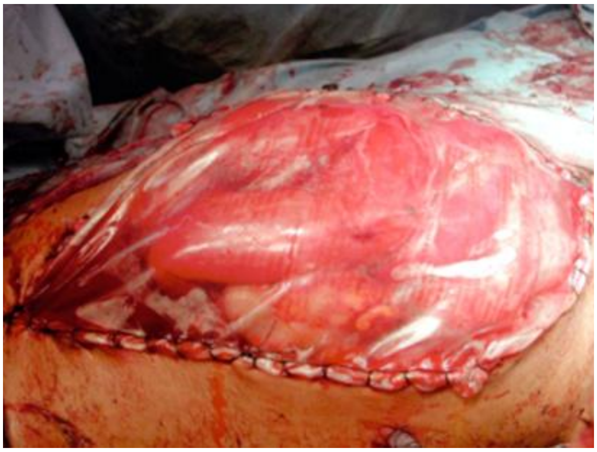
J Trauma. 2006;61:831–836.

"its overall benefit is indisputable"



Bogota bag

- is a sterile plastic bag used for closure of abdominal wounds[1]. It is generally a sterilized, 3 liter genitourinary irrigation bag that is sewn to the skin or fascia of the anterior abdominal wall. Its use was first described by Oswaldo Borraez while a resident in Bogota, Colombia.



The Journal of TRAUMA® Injury, Infection, and Critical Care

Team-Oriented Training for Damage Control Surgery in Rural Trauma: A New Paradigm

Kari Schrøder Hansen, MD, PhD, Per E. Uggen, MD, Guttorm Brattebø, MD, and Torben Wisborg, MD, DEAA

Background: The geography of Norway has led to an initiative to train teams from rural hospitals in damage control surgery using a team-oriented approach based on Crew Resource Management. Our aim was to evaluate this approach and its impact on trauma care in rural hospitals across Norway.

Methods: Thirty-eight teams from 21 hospitals participated in 10 courses (during the years 2003–2006) where providers from the same hospital trained as a team. Each course consisted of interactive lecture modules and operative sessions on live porcine models that emphasize communication, collaboration and team-based problem solving. The data collection tools were a postcourse questionnaire and a phone survey of participating hospitals.

Results: Teams consisted of surgeons (34%), operating room nurses (35%), and anesthesiology staff (31%). Almost all course participants ($N = 228$, 99%) reported a dramatic increase in their proficiency with damage control techniques. There was a mean increase of 2.3 points in proficiency with extraperitoneal pelvic packing and 1.5 points with emergency thoracotomy on a 5-step Likert scale. The team approach was perceived as crucial by 218 (94%) of participants. The phone survey revealed 12 cases of lifesaving rural damage control operations by course participants in the past 3 years (estimated cost: $15,075 per life saved). Of the 18 hospitals surveyed, 17 modified their trauma protocols as a result of the course.

Conclusion: Teaching damage control surgery using a team-oriented approach is an innovative educational method for rural hospitals.

Key Words: Team-training, CRM in trauma, Damage control surgery, Rural trauma, Education, Trauma surgery, Training OR teams.

J Trauma. 2008;64:949–954.

"If it is a trauma patient we leave em all open"

Combat damage control surgery

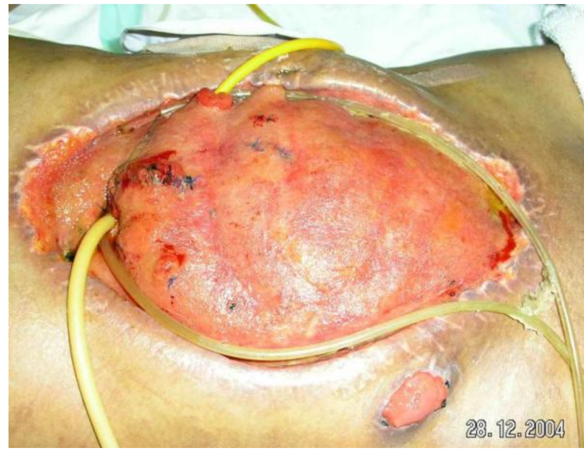
LTC(P) Lorne H. Blackbourne, MD

Background: Although the use of damage control surgery for blunt and penetrating injury has been widely reported and defined, the use of damage control surgery on the battlefield (combat damage control surgery) has not been well detailed.

Discussion: Damage control surgery is now well established as the standard of care for severely injured civilian patients requiring emergent laparotomy in the United States. The civilian damage control paradigm is based on a "damage control trilogy." This trilogy comprises an abbreviated operation, intensive care unit resuscitation, and a return to the operating room for the definitive operation. The goal of damage control surgery and the triology is avoidance of irreversible physiological insult termed the *lethal triad*. The lethal triad comprises the vicious cycle of hypothermia, acidosis, and coagulopathy. Although the damage control model involves the damage control trilogy, abbreviated operation, intensive care unit resuscitation, and definitive operation, all in the same surgical facility, the combat damage control paradigm must incorporate global evacuation through several military surgical facilities and involves up to ten stages to allow for battlefield evacuation, surgical operations, multiple resuscitations, and transcontinental transport.

Summary: Combat damage control surgery represents many unique challenges for those who care for the severely injured patients in a combat zone. (Crit Care Med 2008; 36[Suppl.]: S304–S310)

KEY WORDS: damage control; exploratory laparotomy; Operation Enduring Freedom; Operation Iraqi Freedom



The Journal of TRAUMA® *Injury, Infection, and Critical Care*

Evolution in Damage Control for Exsanguinating Penetrating Abdominal Injury

Jon W. Johnson, MD, Vicente H. Gracias, MD, C. William Schwab, MD, FACS, Patrick M. Reilly, MD, FACS, Donald R. Kauder, MD, FACS, Michael B. Shapiro, MD, FACS, G. Paul Dabrowski, MD, FACS, and Michael F. Rotondo, MD, FACS

Objective: Damage control (DC) has proven valuable in exsanguinated patients. The purpose of this study was to quantify and qualify the impact of current damage control principles applied in a penetrating abdominal injury (PAI) population.

Methods: Over a 3-year period (June 1997–May 2000), of 271 laparotomies for PAI, 24 patients underwent DC (8.9%). Demographics, injury grade, resuscitative and operative parameters, acid-base status, coagulation profiles, fluid/transfusion requirements, definitive repairs, abdominal closure, complications, and outcomes were reviewed. Data were compared with our DC experience a decade earlier. Fisher's exact test was used for comparisons.

Results: Overall survival improved for equivalent Injury Severity Score, Revised Trauma Score, TRISS, admission systolic blood pressure, operating room systolic blood pressure, and Penetrating Abdominal Trauma Index score. Solids (1.2 vs. 1.3), hollow organ (1.5 vs. 1.7), and major vascular injuries (0.5 vs. 0.8) per patient remain unchanged. Currently, there was less hypothermia with equivalent operating room times. In intensive care unit survivors, acid-base status was similar but coagulopathy and hypothermia were less severe. Definitive colon management has shifted from ostomies to anastomoses. Eventual fascial closure occurred in 14 of 19 (74%) compared with 12 of 14 (86%) in the historical group. There were three gastrointestinal fistulae (one pancreatic), one anastomotic leak, and three intra-abdominal abscesses.

Conclusion: Continued application of DC principles has led to improved survival with PAI. Better control of temperature, experience with the open abdomen, and intensive care unit care may be causative.

Key Words: Damage control, penetrating injury.

J Trauma. 2001;51:261–271.

The Journal of TRAUMA® Injury, Infection, and Critical Care

Complications after 344 Damage-Control Open Celiotomies

Richard S. Miller, MD, John A. Morris, Jr., MD, Jose J. Diaz, Jr., MD, Michael B. Herring, MS, and Addison K. May, MD

Background: We reviewed our experience with the open abdomen and hypothesized that the known high wound complication rates were related to the timing and method of wound closure.

Methods: All trauma admissions from 1995 through 2002 requiring an open abdomen and temporary abdominal coverage were included. The study group was then classified by three wound closure methods used in survivors: 1) primary (primary fascial closure); 2) temporizing (skin only, spit thickness skin graft and/or absorbable mesh), and 3) prosthetic (fascial repair using nonabsorbable prosthetic mesh).

Results: In all, 344 patients required an open abdomen and temporary abdominal coverage either as part of a planned staged damage-control celiotomy (66%) or the development of the abdominal compartment syndrome (33%). Of these, 276 patients survived to wound closure. Sixty-nine of the 276 (25%) suffered wound complications (wound infection, abscess, and/or fistula). Thirty-four (12%) died after wound closure; seven of the deaths as a direct result of the wound complication. Complications increased significantly after 8 days ($p < 0.0001$) from the initial operative intervention to fascial closure. Primary fascial closure was achieved in 180 of 276 (65%) patients. Although there was no difference in the mean Injury Severity Score between the three groups, the primary group had significantly fewer mean transfusion requirements, shorter mean time to fascial closure, and a lower complication rate as compared with either the temporizing or prosthetic groups. The primary group thus incurred significantly less mean initial hospitalization charges.

Conclusion: Morbidity associated with wound complications from the open abdomen remains high (25%). Morbidity is associated with the timing and method of wound closure and transfusion volume, but independent on injury severity. Also, delayed primary fascial closure before 8 days is associated with the best outcomes with the least charges.

Key Words: Damage control, Abdominal compartment syndrome, Complications, Open abdomen.

J Trauma. 2005;59:1365–1374.

Results

- The mean number of operations was 4.6
- Overall mortality of 28%
- ICU LOS
- LOS – 32
- 63 patien
- 58 closure with polyglactin mesh
- 44 intra-abdominal infections
- 18 enterocutaneous fistulas
- All 63 survivors were readmitted at least once
- There were a total of 186 readmissions
- 92 subsequent surgical procedures

OMG!!!!

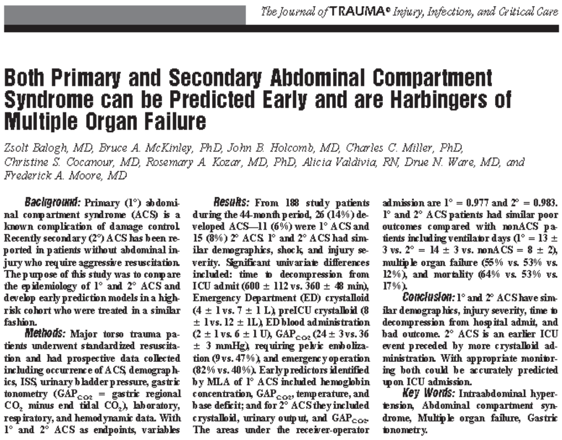
Damage control surgery for abdominal trauma.

Cirocchi R, et al. Cochrane Database Syst Rev. 2010 Jan 20;(1):CD007438.

We searched the Cochrane Injuries Group Specialised Register, CENTRAL (The Cochrane Library 2008, Issue 3), MEDLINE, EMBASE, Web of Science: Science Citation Index & ISI Proceedings, Current Controlled Trials MetaRegister, Clinicaltrials.gov, Zetoc, and CINAHL for all published and unpublished randomised controlled trials. We did not restrict the searches by language, date, or publication status.

- A total of 1523 studies were identified.
- No randomised controlled trials comparing DCS with immediate and definitive repair in patients with major abdominal trauma were found.
- 1521 studies were excluded because they were not relevant to the review topic
- two studies were excluded because they were case-control studies.

AUTHORS' CONCLUSIONS:
Evidence that supports the efficacy of DCS with respect to traditional laparotomy in patients with major abdominal trauma is limited.



The Journal of TRAUMA® Injury, Infection, and Critical Care

Both Primary and Secondary Abdominal Compartment Syndrome can be Predicted Early and are Harbingers of Multiple Organ Failure

Zsolt Balogh, MD, Bruce A. McKinley, PhD, John B. Holcomb, MD, Charles C. Miller, PhD, Christine S. Cocanour, MD, Rosemary A. Kozar, MD, PhD, Alicia Valdivia, RN, Drue N. Ware, MD, and Frederick A. Moore, MD

Background: Primary (1°) abdominal compartment syndrome (ACS) is a known complication of damage control. Recently secondary (2°) ACS has been reported in patients without abdominal injury who require aggressive resuscitation. The purpose of this study was to compare the epidemiology of 1° and 2° ACS and develop early prediction models in a high-risk cohort who were treated in a similar fashion.

Methods: Major torso trauma patients underwent standardized resuscitation and had prospective data collected including occurrence of ACS, demographics, ISS, urinary bladder pressure, gastric tonometry (GAP_{CO2} = gastric regional CO_2 minus end tidal CO_2), laboratory, respiratory, and hemodynamic data. With 1° and 2° ACS as endpoints, variables

Results: From 188 study patients during the 44-month period, 26 (14%) developed ACS—11 (6%) were 1° ACS and 15 (8%) 2° ACS. 1° and 2° ACS had similar demographics, shock, and injury severity. Significant univariate differences included: time to decompression from ICU admit (600 ± 112 vs. 360 ± 48 min), Emergency Department (ED) crystalloid (4 ± 1 vs. 7 ± 1 L), preICU crystalloid (8 ± 1 vs. 12 ± 1L), ED blood administration (2 ± 1 vs. 6 ± 1 U), GAP_{CO2} (24 ± 3 vs. 36 ± 3 mmHg), requiring pelvic embolization (9 vs. 47%), and emergency operation (82% vs. 40%). Early predictors identified by MLA of 1° ACS included hemoglobin concentration, GAP_{CO2}, temperature, and base deficit; and for 2° ACS they included crystalloid, urinary output, and GAP_{CO2}. The areas under the receiver-operator admission are 1° = 0.977 and 2° = 0.983. 1° and 2° ACS patients had similar poor outcomes compared with nonACS patients including ventilator days (1° = 13 ± 3 vs. 2° = 14 ± 3 vs. nonACS = 8 ± 2), multiple organ failure (55% vs. 53% vs. 12%), and mortality (64% vs. 53% vs. 17%).

Conclusion: 1° and 2° ACS have similar demographics, injury severity, time to decompression from hospital admit, and bad outcome. 2° ACS is an earlier ICU event preceded by more crystalloid administration. With appropriate monitoring both could be accurately predicted upon ICU admission.

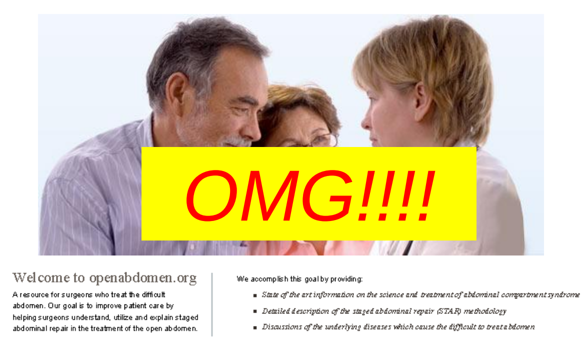
Key Words: Intraabdominal hypertension, Abdominal compartment syndrome, Multiple organ failure, Gastric tonometry.

Abdominal compartment syndrome

- occurs when the abdomen becomes subject to increased pressure. Specific cause of abdominal compartment syndrome is not known, although some causes can be sepsis and severe abdominal trauma. Increasing pressure reduces blood flow to abdominal organs and impairs pulmonary, cardiovascular, renal, and gastro-intestinal (GI) function, causing multiple organ dysfunction syndrome and death.[1]

websites

- IntraAbdominalHypertension.org
- OpenAbdomen.org
- OpenAbdomen.com
- World Society of Abdominal compartment syndrome
- World society of abdominal compartment syndrome management

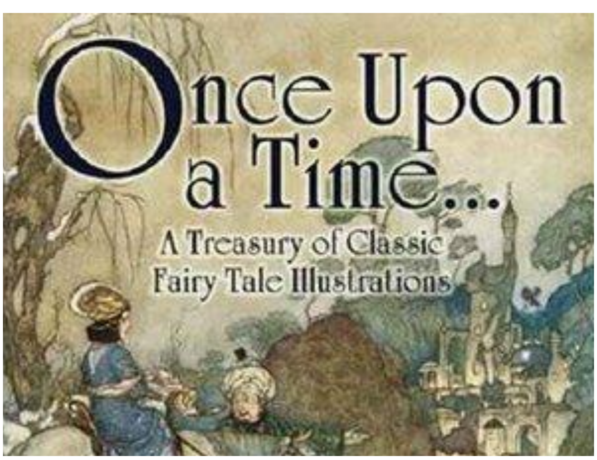


Damage Control Resuscitation Reduces Resuscitation Volumes And Improves Survival In 390 Damage Control Laparotomy Patients

Bryan A Cotton, MD*, Neeti Reddy, MD*, Quinton M Hatch, MD*, Eric LeFebvre, MD*, Charles E Wade, MD*, Rosemary A Kozar, MD, Brijesh S Gill, MD*, Rondel Albarado, MD*, Michelle K McNutt, MD*, John B Holcomb, MD
University of Texas Health Science Center-Houston, Houston, TX

OBJECTIVE: Damage control laparotomy (DCL) focuses on control of hemorrhage and gross bowel spillage. Damage control resuscitation (DCR) aims at preventing coagulopathy through limiting crystalloids and delivering higher ratios of plasma and platelets. The purpose of the study was to determine if implementation of DCR in DCL patients would translate to improved survival.
METHODS: A retrospective review of all emergent trauma laparotomies between 01/2004-08/2010 was performed. Patients were divided into pre-DCR and DCR groups, and were excluded if they died prior to completion of the initial laparotomy. The lethal triad was defined as temperature 1.5, or pH<7.30.
RESULTS: 1217 patients were included, 390 (32%) underwent DCL. Of these, 282 were pre-DCR and 108 were DCR. Groups were similar in demographics, injury severity, arrival vitals and laboratory values. DCR patients received less crystalloids (median 14L vs. 5L), RBC (13U vs. 7U), plasma (11U vs. 8U) and platelets (6U vs. 0U) by 24-hr; all p<0.05. DCR had less evidence of the lethal triad upon ICU arrival (88% vs. 46%, p<0.001). 24-hour and 30-day survival was higher in DCR (88% vs. 97%, p=0.006 and 76% vs. 86%, p=0.03). After controlling for age, injury severity and ED variables, multivariate analysis demonstrated DCR was associated with a significant increase in 30-day survival (Odds ratio 2.5, 95% C.I. 1.10-5.58, p=0.03).
CONCLUSIONS: In severely injured patients undergoing DCL, this new resuscitation paradigm resulted in reduced crystalloid and blood product administration and was associated with an improvement in 30-day survival.

RESULTS: 1217 patients were included, 390 (32%) underwent DCL.



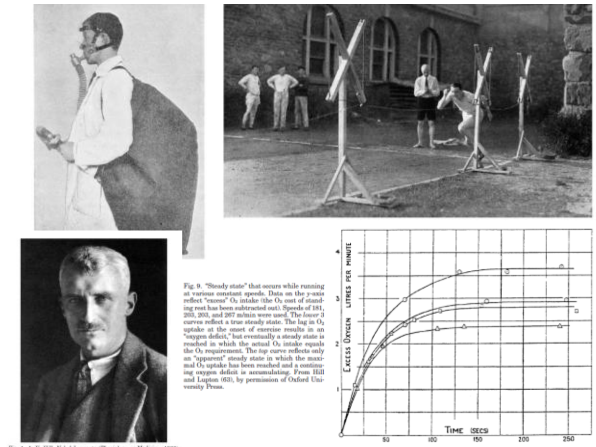
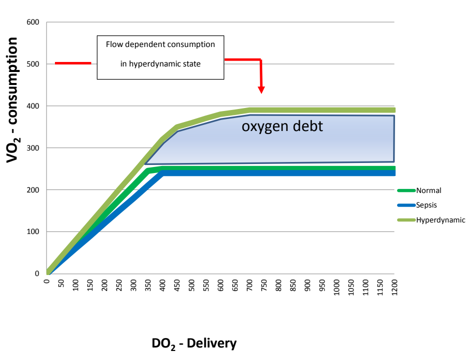
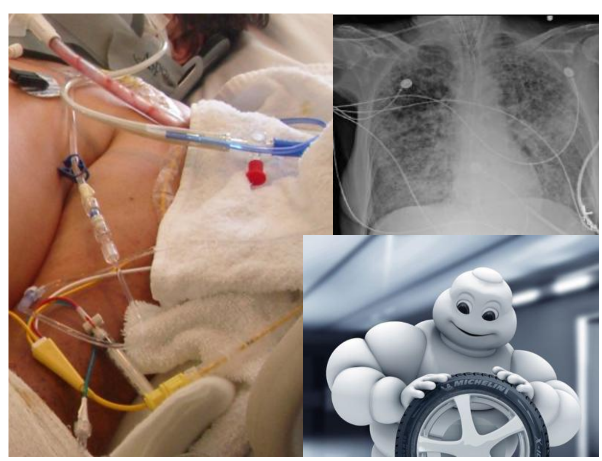


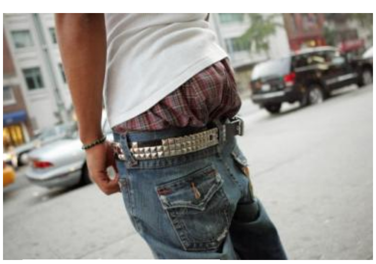
Fig. 9. "Steady state" that occurs while running at various constant speeds. Data on the y-axis reflect "excess" O2 intake (the O2 cost of standing rest has been subtracted out). Speeds of 181, 203, 203, and 267 m/min were used. The lower 3 curves reflect a true steady state. The lag in O2 uptake at the onset of exercise results in an "oxygen deficit," but eventually a steady state is reached in which the actual O2 intake equals the O2 requirement. The top curve reflects only an "apparent" steady state in which the maximal O2 uptake has been reached and a continuing oxygen deficit is accumulating. From Hill and Lupton (63), by permission of Oxford University Press.
Excess Oxygen Litres per minute
Time (secs)


Flow dependent consumption
in hyperdynamic state
oxygen debt
VO2 - consumption
DO2 - Delivery
Normal
Sepsis
Hyperdynamic

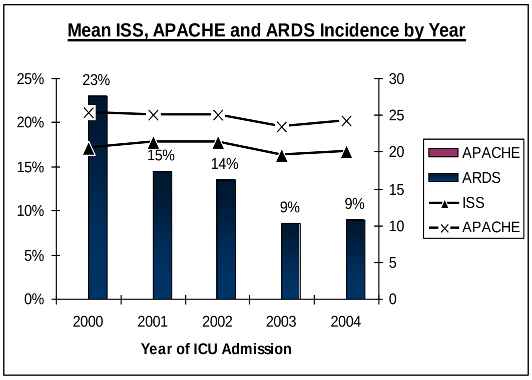

MICHELIN

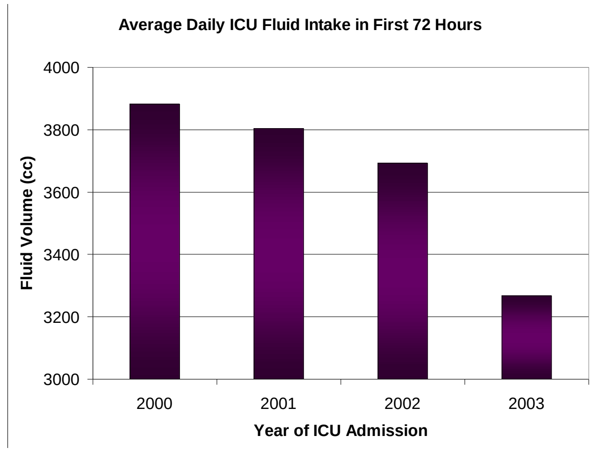



Purple cool aid







ORIGINAL ARTICLE

Damage Control Laparotomy: A Vital Tool Once Overused

Guillermo Higa, MD, Randall Friese, MD, Terence O'Keeffe, MD, MSPH, Julie Wynne, MD, Paul Bowlby, RN, Michelle Ziemba, RN, Rifat Latifi, MD, Narong Kulvatunyou, MD, and Peter Rhee, MD, MPH

Background: Trauma surgery is in constant evolution as is the use of damage control laparotomy (DCL). The purpose of this study was to report the change in usage of DCL over time and its effect on outcome.
Methods: Trauma patients requiring laparotomies during a 3-year (2006–2008) period were reviewed. DCL was defined as laparotomy when fascia was not closed at the first operation.
Results: There were 14,534 trauma patients evaluated, and 843 laparotomies were performed on 532 patients during the study period. The number of patients requiring open laparotomies slightly increased while the demographics and Injury Severity Score were similar during the study period. The number of patient requiring DCL significantly decreased from 36.3% (53 of 146) in 2006 to 8.8% (15 of 170) in 2008 ($p < 0.001$). During this same time period, the mortality rate for patients requiring open laparotomy significantly decreased from 21.9% in 2006 to 12.9% in 2008 ($p = 0.05$). The decreased use of DCL resulted in a 33.3% reduction in the number of laparotomies performed. The decrease in average costs and charges is projected to result in savings of $2.2 million and $5.8 million, respectively.
Conclusions: The use of DCL was significantly decreased by 78% during the study with significantly improved outcome. The improved outcome and decreased resource utilization can reduce health care costs and charges. Although DCL may be a vital aspect of trauma surgery, it can be used more selectively with improved outcome.

(*J Trauma.* 2010;69: 53–59)

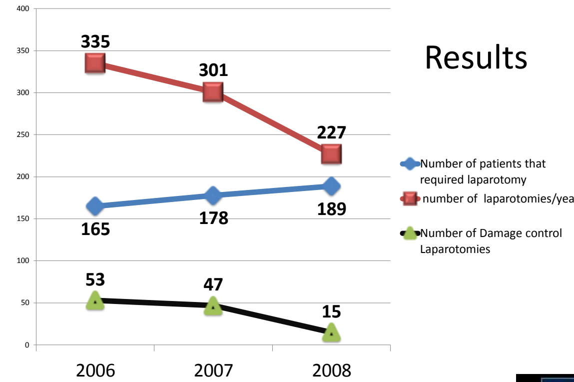
Results

	2006	2007	2008	p value
Trauma patients	4,721	4,877	4,936	
Any laparotomy	165	178	189	0.38
Laparoscopies	19	19	19	0.98
Laparotomies	146	159	170	0.36
Definitive Laparotomy	93	112	155	**<0.001**
Damage Control	53	47	15	**<0.001**

Results

	2006	2007	2008	p value
Total deaths	32	27	22	
Died on OR Table	13	9	6	0.47
Died within 6 hours out of OR	9	8	5	0.89
Died - head injury	3	5	5	0.33
Died - sepsis / MODS	5	3	6	0.48
Died - ACS	2	2	0	0.64
Died after Damage control	19	13	8	0.17

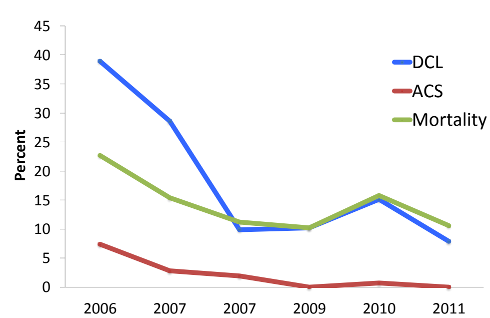
Results



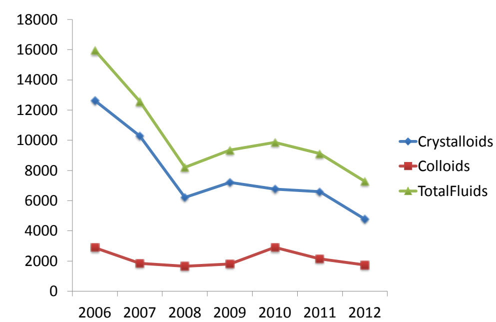
SUMMARY

- Damage Control laparotomy
  - 32% to 8%
  - 75% less DCL
- Overall mortality
  - 21.9% to 12.9%
- Savings
  - Charges - $5,800,000
  - Costs - $2,200,000

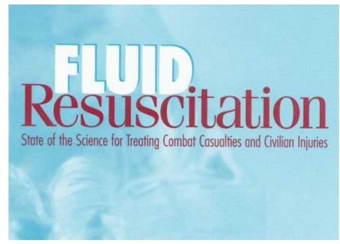
Abdominal Compartment Syndrome



Fluid use over time

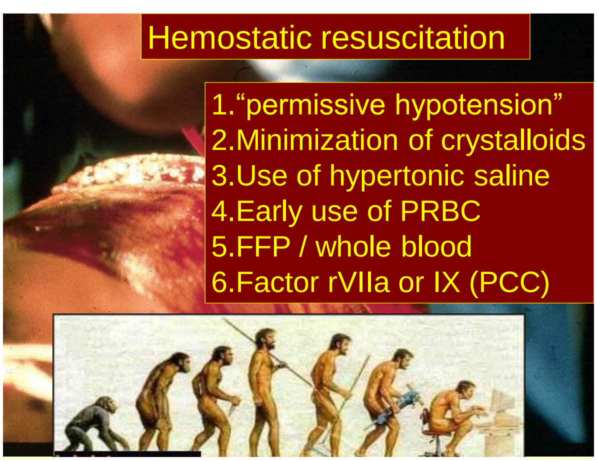


Institute of Medicine



Committee on Fluid Resuscitation for Combat Casualties
Institute of Medicine, National Academy Press
Washington, DC 1999.

- David Longnecker (Chair)
  - Univ Penn Health System
- William G Baxt
  - Univ Penn Health System
- Joseph C Fratantoni
  - Biologics, C.L. McIntosh & Associates
- Jureta W. Horton
  - U Tex SWMS
- John P. Kampine
  - MC Wisconsin
- Harvey G. Klein
  - NIH
- Joseph E. Rall
  - NIH
- George F Sheldon
  - UNC
- Blane C. White
  - Wayne State USM



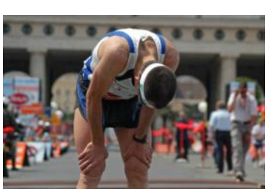
Hemostatic resuscitation

1. "permissive hypotension"
2. Minimization of crystalloids
3. Use of hypertonic saline
4. Early use of PRBC
5. FFP / whole blood
6. Factor rVIIa or IX (PCC)

- The goals of trauma laparotomy:
  - Hemorrhage
  - Contamination
  - Diagnosis
  - Reconstruction

DAMAGE CONTROL LAPAROTOMY

- Trend towards limiting DCL unless absolutely required



how to hurt a bleeding patient

- Resuscitate
  - No stop the bleeding
- Optimize – supernormal – oxygen delivery
  - Swan ganz catheter
- Damage control surgery
  - open belly!!

iatrogenic

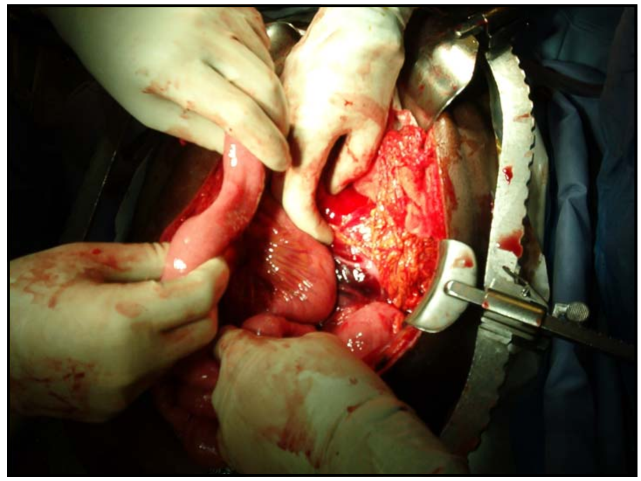
inadvertent adverse effect or complication resulting from medical treatment or advice,

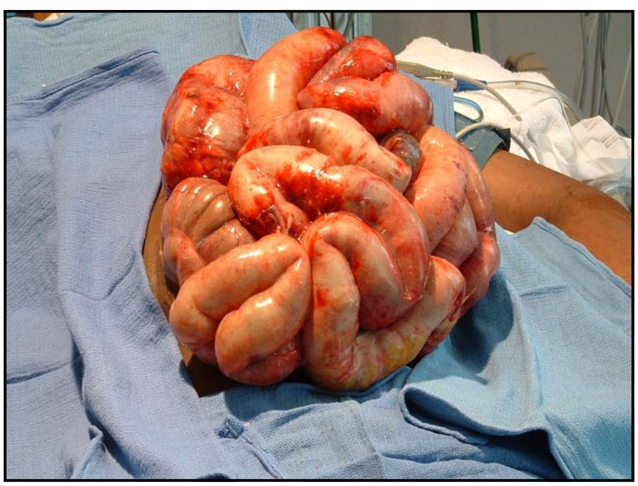
American iatrogenic Association
Promoting accountability for medical professionals and institutions


END

New ICU Fluid Resuscitation Strategies for Damage Control Patients

Bryan A Cotton, MD, MPH
Associate Professor of Surgery
Department of Surgery and
The Center for Translational Injury Research
University of Texas Health Science Center
Houston, Texas





Why Crystalloids?

- inexpensive ($1.15 per 1.0L bag)
- easy to store, long shelf life, readily available
- familiarity
- ***very low incidence of adverse reactions*?**

Historical Background

- A plea for "moderation" is made
  Moore FD Metabolic care of the surgical patient, 1959
  Shires T et al Ann Surg , 1961
  Moore FD, Shires G Ann Surg, 1967
- Supra-normal resuscitation
  Shoemaker WC et al Am J Surg, 1983
- Abbreviated laparotomy for lethal coagulopathy
  Stone HH et al Ann Surg, 1983

CRITICAL CARE MEDICINE
Vol. 4, No. 2
Printed in U.S.A.

Fluid resuscitation following injury: rationale for the use of balanced salt solutions

CHARLES J. CARRICO, MD; PETER C. CANIZARO, MD; G. TOM SHIRES, MD

- LR: "to replace interstitial fluid" and "support the intravascular volume until type specific WB available"
- LR at a "very rapid rate," 1000-2000 ml over 45 minutes "until whole blood is available."
- Base further WB transfusion on the patients response

Historical Background

- A plea for "moderation" is made
  Moore FD Metabolic care of the surgical patient, 1959
  Shires T et al Ann Surg , 1961
  Moore FD, Shires G Ann Surg, 1967
- Supra-normal resuscitation
  Shoemaker WC et al Am J Surg, 1983
- Abbreviated laparotomy for lethal coagulopathy
  Stone HH et al Ann Surg, 1983

Historical Background

- Damage control- improved outcomes with exsanguinating, penetrating torso trauma
  Rotondo et al J Trauma. 1993
- ACS as a result of “massive interstitial” and “retroperitoneal swelling”
  Fietsam R et al Am Surg, 1989
  Eddy VA et al J Tenn Med Assoc, 1994
  Bendahan J et al J Trauma, 1995

“The trauma surgeon told me I was lucky to be alive and not on dialysis.
Yep, at least I still have my kidneys!”

DCL and closure rates

- Damage control surgery has revolutionized trauma surgery.
- Rates of successful fascial closure in multicenter studies:
  - o WTA – 70% (2012)
  - o AAST – 61% (2012).

Burlew and colleagues. Who Should We Feed? A Western Trauma Association Multi-Institutional Study of Enteral Nutrition in the Open Abdomen after Injury. J Trauma Acute Care Surg. 2012

DuBose and colleagues. Open Abdomen Management after Damage Control Laparotomy for Trauma: a Prospective, Observational American Association for the Surgery of Trauma Multicenter Trial. J Trauma Acute Care Surg. 2013

DCL and closure rates

Current Use of Damage-Control Laparotomy, Closure Rates, and Predictors of Early Fascial Closure at the First Take-Back

Quinton M. Hatch, MD, Lisa M. Osterhout, BS, Asma Ashraf, MD, Jeanette Podbielski, BSN, Rosemary A. Kozar, MD, PhD, Charles E. Wade, PhD, John B. Holcomb, MD, and Bryan A. Cotton, MD, MPH

The Journal of TRAUMA® Injury, Infection, and Critical Care • Volume 70, Number 6, June 2011

- DCL in 30% of emergent laparotomies
- 75% fascial closure rate.

Impact of Closure at the First Take Back: Complication Burden and Potential Overutilization of Damage Control Laparotomy

Quinton M. Hatch, MD, Lisa M. Osterhout, BS, Jeanette Podbielski, BSN, Rosemary A. Kozar, MD, PhD, Charles E. Wade, PhD, John B. Holcomb, MD, and Bryan A. Cotton, MD, MPH

Demographics			
Median age, yr (IQR)	33 (24–49)	38 (28–46)	0.426
Male gender	80%	77%	0.475
Blunt mechanism	65%	60%	0.476
Median ISS (IQR)	22 (14–34)	27 (17–38)	0.130
Median head AIS (IQR)	0 (0–3)	0 (0–3)	0.416
Median chest AIS (IQR)	0 (2–4)	0 (3–4)	0.116
Median abdomen AIS (IQR)	3 (3–4)	3 (3–4)	0.713
Prehospital and ED variables			
Median prehospital fluids, L (IQR)	1.0 (0.6–1.5)	1.0 (0.5–1.6)	0.784
Median ED SBP, mm Hg (IQR)	96 (77–129)	96 (74–123)	0.459
Median ED fluids, L (IQR)	1.5 (0.5–3.0)	1.5 (0.6–2.5)	0.800
Median ED pH (IQR)	7.26 (7.15–7.32)	7.24 (7.13–7.30)	0.414
Median ED INR value (IQR)	1.13 (1.05–1.36)	1.29 (1.11–1.48)	0.010*
OR and ICU variables			
Median OR SBP, mm Hg (IQR)	117 (100–138)	109 (84–133)	0.121
Median OR fluids, L (IQR)	4.1 (2.8–5.5)	4.5 (3.0–7.0)	0.291
Median OR RBC, U (IQR)	5 (1–11)	9 (4–17)	<0.001*
Median OR pH (IQR)	7.27 (7.19–7.32)	7.19 (7.12–7.27)	<0.001*
Median ICU SBP, mm Hg (IQR)	142 (117–165)	131 (110–163)	0.082
Median ICU INR (IQR)	1.4 (1.2–1.5)	1.5 (1.3–1.7)	0.028*
Median ICU pH (IQR)	7.33 (7.29–7.38)	7.31 (7.25–7.37)	0.036*
Median ICU temperature, °F (IQR)	95.4 (94.6–97.2)	94.7 (95.9–93.0)	0.002*
Median 24-h fluids, L (IQR)	11.9 (8.0–16.8)	15.5 (9.6–21.4)	0.006*
Median 24-h PRBC, U (IQR)	8 (4–14)	15 (7–26)	<0.001*

Impact of Closure at the First Take Back: Complication Burden and Potential Overutilization of Damage Control Laparotomy

Quinton M. Hatch, MD, Lisa M. Osterhout, BS, Jeanette Podbielski, BSN, Rosemary A. Kozar, MD, PhD, Charles E. Wade, PhD, John B. Holcomb, MD, and Bryan A. Cotton, MD, MPH

TABLE 4. Logistic Regression Model Predicting the Development of Noninfectious Abdominal Complications (Ileus, Bowel Obstruction, Ischemic Bowel, and Anastomotic Breakdown)

	Odds Ratio	95% Confidence Interval	*p*
Age, yr	0.99	0.97–1.02	0.867
Male gender	1.68	0.67–4.22	0.266
ISS	0.96	0.93–0.98	0.006*
Large bowel injury	1.27	0.63–2.53	0.493
Intraoperative transfusions, units	1.00	0.97–1.03	0.760
Closed at initial take back	0.23	0.09–0.56	0.001*

TABLE 3. Logistic Regression Model Predicting the Development of Abdominal Infections (Intra-Abdominal Abscess, Retroperitoneal Abscess, and Pelvic Abscess)

	Odds Ratio	95% Confidence Interval	*p*
Age, yr	1.00	0.98–1.03	0.461
Male gender	1.06	0.46–2.40	0.891
ISS	0.97	0.95–1.00	0.061
Large bowel injury	1.88	0.96–3.67	0.063
Intraoperative transfusions, units	0.99	0.97–1.02	0.975
Closed at initial take back	0.28	0.12–0.66	0.004*

TABLE 5. Logistic Regression Model Predicting the Development of Abdominal Wound Complications (Surgical Site Infection, Incisional Hernia, and Dehiscence)

	Odds Ratio	95% Confidence Interval	*p*
Age, yr	0.98	0.96–1.01	0.281
Male gender	0.62	0.28–1.33	0.219
ISS	0.98	0.96–1.01	0.362
Large bowel injury	1.87	0.96–3.66	0.065
Intraoperative transfusions, units	0.99	0.97–1.02	0.848
Closed at initial take back	0.31	0.13–0.72	0.007*

TABLE 6. Logistic Regression Model Predicting the Development of Pulmonary Complications (Ventilator-Dependent Respiratory Failure, Ventilator-Associated Pneumonia, and Empyema)

	Odds Ratio	95% Confidence Interval	*p*
Age, yr	1.01	0.99–1.02	0.282
Male gender	1.05	0.54–2.04	0.870
Chest AIS	1.20	1.03–1.40	0.014*
Urgent thoracotomy/sternotomy	1.38	0.57–3.31	0.473
Intraoperative transfusions, units	0.97	0.91–1.04	0.484
Closed at initial take back	0.35	0.20–0.62	<0.001*

PAPER OF THE 131ST ASA ANNUAL MEETING

Annals of Surgery • Volume 254, Number 4, October 2011

Damage Control Resuscitation Is Associated With a Reduction in Resuscitation Volumes and Improvement in Survival in 390 Damage Control Laparotomy Patients

Bryan A. Cotton, MD, MPH,† Neeti Reddy, BS,† Quinton M. Hatch, MD,† Eric LeFebvre, BS,† Charles E. Wade, PhD,† Rosemary A. Kozar, MD, PhD,* Brijesh S. Gill, MD,* Rondel Albarado, MD,* Michelle K. McNutt, MD,* and John B. Holcomb, MD*†*

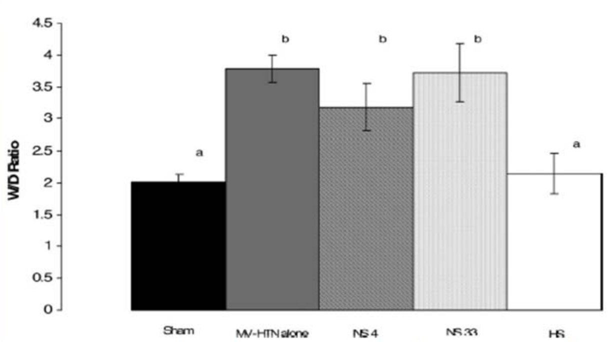
TABLE 3. Comparison of ICU, In-hospital, and Outcome Variables

Variables	Pre-DCR (n = 282)	DCR (n = 108)	*P*
In-hospital variables			
Median 24-hr fluid administration, L (IQR)	13.9 (9.4–20.0)	5.0 (3.8–8.9)	<0.001
Median 24-hr RBC transfusion, U (IQR)	13 (5–22)	8 (3–16)	0.001
Median 24-hr plasma transfusion, U (IQR)	11 (5–20)	8 (2–18)	0.029
Median 24-hr platelet transfusion, U (IQR)	6 (0–12)	0 (0–12)	0.005
Outcome variables			
Median length of stay, days (IQR)	22 (9–42)	19 (11–33)	0.601
Median ICU length of stay, days (IQR)	9 (3–20)	7 (3–16)	0.421
Median ventilator-free days (IQR)	17 (1–25)	20 (9–26)	0.134
Discharged with open abdomen%	13.8%	9.6%	0.298
Acute renal failure, %	15.6%	8.3%	0.060
Acute respiratory distress syndrome, %	4.6%	0.9%	0.080
Multiorgan failure	6.0%	2.0%	0.107
24-hr survival, %	88%	97%	0.007
30-day survival, %	76%	86%	0.030

Hypertonic saline resuscitation prevents hydrostatically induced intestinal edema and ileus

Crit Care Med 2006 Vol. 34, No. 6

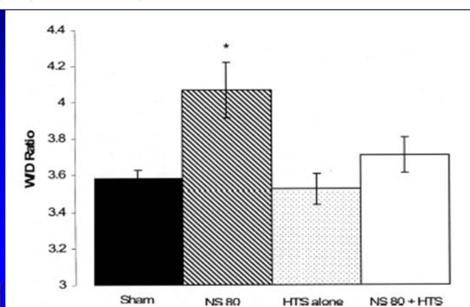
Ravi S. Radhakrishnan, MD; Hasen Xue, MD; Stacey D. Moore-Olufemi, MD; Norman W. Weisbrodt, PhD; Frederick A. Moore, MD; Steven J. Allen, MD; Glen A. Laine, PhD; Charles S. Cox Jr, MD



Hypertonic saline reverses stiffness in a Sprague–Dawley rat model of acute intestinal edema, leading to improved intestinal function

Crit Care Med 2007 Vol. 35, No. 2

Ravi S. Radhakrishnan, MD; Hari R. Radhakrishnan, BA; Hasen Xue, MD; Stacey D. Moore-Olufemi, MD; Anshu B. Mathur, PhD; Norman W. Weisbrodt, PhD; Frederick A. Moore, MD; Steven J. Allen, MD; Glen A. Laine, PhD; Charles S. Cox Jr, MD



Damage Control Immunoregulation: Is There a Role for Low-Volume Hypertonic Saline Resuscitation in Patients Managed with Damage Control Surgery?

JUAN C. DUCHESNE, M.D.,* ERIC SIMMS, M.D.,* CHRISSY GUIDRY, D.O.,* MARQUINN DUKE, M.D.,* ESTHER BEESON, M.D.,* NORMAN E. McSWAIN, M.D.,* BRYAN COTTON, M.D., M.P.H.†

*From *Trauma/Critical Care, Tulane University School of Medicine, New Orleans, Louisiana; and †The University of Texas Medical School at Houston, Houston, Texas*

TABLE 1. *Demographics*

Univariate Analysis	3% HTS (n = 76)	ICS (n = 112)	*P* Value
Mean (SD) age, years	40 (17)	40 (15)	0.91
Male gender, %	80	77	0.57
Penetrating injury (%)	36 (70.5)	44 (57.8)	0.19
Mean (SD) SBP, mm of Hg	117 (24)	119 (24)	0.56
Mean (SD) GCS	15 (0.4)	15 (0.4)	0.45
Initial hemoglobin (SD)	10.3 (1.2)	10.7 (1.4)	0.23
Initial base deficit (SD)	–8.9 (4.2)	–9.2 (5.7)	0.41
Mean (SD) ISS	26 (6)	27 (6)	0.84
Mean FFP (units)	11.4 (8.1)	9.2 (6.2)	0.15
Mean PRBC (units)	20.5 (12.1)	15.7 (11.0)	0.47
FFP:PRBC ratio	0.56	0.58	0.58

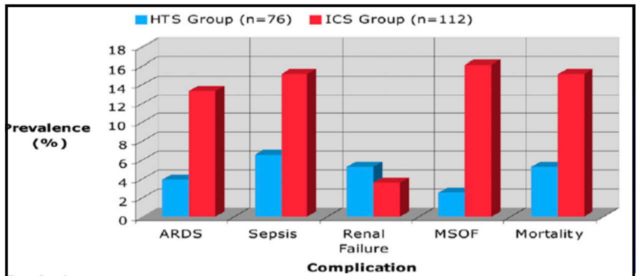
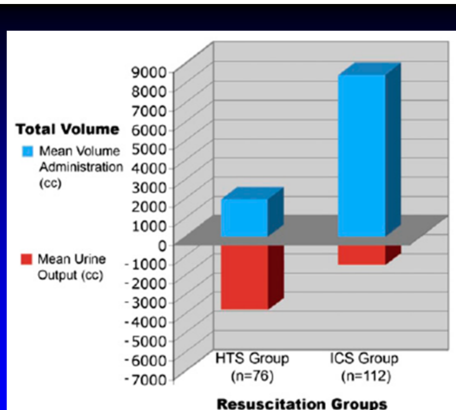


TABLE 2. *Outcomes*

Resuscitation Groups	3% HTS (n = 76)	ICS (n = 112)	*P* Value
TICU LOS, mean	10 (8)	16 (15)	<0.01
Change in LOS	0.00 (ref.)	+5.3	<0.01*
ARDS, prevalence %	4.0	13.4	0.02
Prevalence ratio (95% CI)	1.00 (ref.)	3.60 (1.09–11.95)	0.04*
Sepsis, prevalence %	6.6	15.2	0.06
Prevalence ratio (95% CI)	1.00 (ref.)	2.34 (0.91–6.02)	0.08*
Renal failure, prevalence, %	5.3	3.6	0.58
Prevalence ratio (95% CI)	1.00 (ref.)	0.61 (0.14–2.69)	0.51
MSOF, prevalence, %	2.6	16.1	<0.01
Prevalence ratio (95% CI)	1.00 (ref.)	5.96 (1.42–24.91)	0.01*
Death, prevalence, %	5.3	15.2	0.03
Prevalence ratio (95% CI)	1.00 (ref.)	3.65 (1.25–10.69)	0.02*



ORIGINAL ARTICLE

Chasing 100%: the use of hypertonic saline to improve early, primary fascial closure after damage control laparotomy

John A. Harvin, MD, Mark Mims, BS, Juan C. Duchesne, MD, Charles S. Cox Jr, MD, Charles E. Wade, PhD, John B. Holcomb, MD, *and* Bryan A. Cotton, MD, MPH, *Houston, Texas*

- 3% sodium chloride at 30 mL/hr.
  - o Rate not titrated.
  - o No additional maintenance fluids.
  - o Additional resuscitative fluids dictated by patient’s clinical condition.
- Rate and concentration chosen based upon relatively similar [NaCl] with NS at 100 mL/hr.

Methods

- Prospective performance improvement project
- January 2010 to January 2012.
- Excluded: <18 years of age, pregnancy, incarceration, death prior to first take back.

Methods

- Two groups:
  - o HTS – received 3% NaCl fluids at 30 mL/hr.
  - o STD – maintenance fluids not controlled.
- Primary outcome: early, primary fascial closure (EPFC):
  - o Primary fascial closure within 7 days.

All Patients

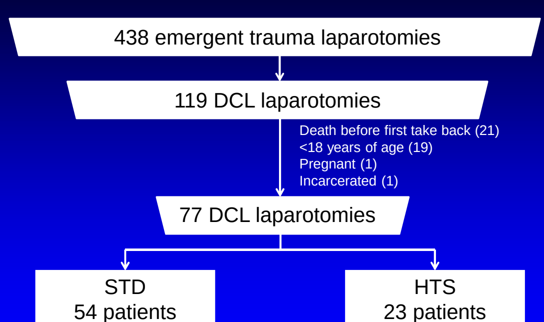


TABLE 1. Demographic and Injury Characteristics of STD and HTS Fluid Groups

	STD (n = 54)	HTS (n = 23)	*p*
Median age, years	34 (23–51)	31 (23–48)	0.528
Male gender, %	72	86	0.147
White race, %	56	52	0.749
Median BMI	26 (24–31)	29 (24–32)	0.522
Blunt mechanism, %	72	60	0.291
Median head AIS	0 (0–3)	0 (0–1)	0.214
Median chest AIS	3 (0–3)	3 (0–3)	0.966
Median abdomen AIS	4 (3–4)	4 (3–4)	0.794
Median extremity AIS	0 (0–3)	2 (0–3)	0.150
Median ISS	29 (18–41)	25 (19–34)	0.418

TABLE 2. ED Vital Signs, Laboratory Values, and Resuscitation Fluids

	STD (n = 54)	HTS (n = 23)	*p*
Initial ED vital signs, laboratory values, and resuscitation volumes			
Median SBP, mm Hg	92 (80 to 119)	102 (80 to 121)	0.473
Median pulse, beats/min	105 (84 to 128)	119 (93 to 145)	0.146
Median hemoglobin, g/dL	12.5 (11.1 to 14.1)	12.6 (11.4 to 14.0)	0.975
Median INR	1.2 (1.1 to 1.4)	1.3 (1.1 to 1.6)	0.921
Median base value, mmol/L	−7 (−10 to −3)	−8 (−13 to −5)	0.303
Median crystalloids, mL	1,000 (0 to 1,450)	1,000 (0 to 1,000)	0.330
Median RBC, U	1 (0 to 3)	1 (0 to 3)	0.932
Median plasma, U	1 (0 to 2)	1 (0 to 2)	0.713

	STD (n = 54)	HTS (n = 23)	*p*
24-hour fluids and blood products			
Median crystalloids, mL	7,825 (5,600–10,235)	3,870 (2,770–6,770)	<0.001
Median RBC, U	10 (3–16)	9 (4–17)	0.776
Median plasma, U	9 (2–16)	8 (2–12)	0.775
Median platelet, U	3 (0–6)	3 (0–9)	0.646
48-hour fluids and blood products			
Median crystalloids, mL	11,180 (9,200–13,890)	6,290 (4,300–9,495)	<0.001
Median RBC, U	10 (4–17)	9 (4–18)	0.721
Median plasma, U	10 (2–17)	8 (2–12)	0.616
Median platelet, U	6 (0–9)	3 (0–12)	0.631
72-hour fluids and blood products			
Median crystalloids, mL	13,890 (11,350–17,630)	8,630 (6,770–13,655)	<0.001
Median RBC, U	11 (4–17)	10 (5–18)	0.743
Median plasma, U	10 (2–17)	8 (2–13)	0.599
Median platelet, U	9 (0–9)	3 (0–12)	0.673
Renal function at 72 hours			
Median peak sodium, mEq/L	146 (143–148)	148 (146–152)	0.037
Median delta sodium, mEq/L	5 (2–7)	7 (3–11)	0.073
Median peak creatinine, mg/dL	1.3 (1.1–1.7)	1.4 (1.1–1.6)	0.562
Median delta creatinine, mg/dL	0.0 (0.0–0.2)	0.0 (0.0–0.2)	0.245
Median RIFLE score	0 (0–2)	0 (0–1)	0.388

TABLE 5. Primary and Secondary Outcomes between STD and HTS Groups

	STD (n = 54)	HTS (n = 23)	*p*
EPFC, %	76	100	0.010
Median time to fascial closure, hour	50 (35–127)	33 (21–48)	0.001
Median ICU-free days	15 (6–23)	23 (7–26)	0.163
Median ventilator-free days	22 (14–27)	26 (12–28)	0.138
24-hour mortality, %	4.7	0.0	0.290
30-day mortality, %	9.4	8.7	0.923

TABLE 6. Multivariate Models Predicting Closure Rates

	Odds ratio	95% CI	*p*
Closure at initial take back			
Blunt mechanism	0.46	0.112–1.885	0.280
ISS	1.01	0.951–1.066	0.817
ED base value	1.07	0.965–1.207	0.298
ED SBP, mm Hg	0.98	0.948–1.004	0.127
HTS infusion	3.87	1.228–14.334	0.022
Closure by day 7			
Blunt mechanism	0.15	0.014–1.556	0.110
ISS	1.00	0.938–1.069	0.959
ED base value	1.05	0.896–1.236	0.538
ED SBP, mm Hg	0.99	0.969–1.103	0.452
HTS infusion	Value for colinearity (i.e., HTS independently predicted closure)		

Limitations

- Single institution study.
- No randomization to therapy.
- No control for indication of DCL.
- No control of maintenance fluids.

Conclusions

- Animal models show HTS mitigates and reverses resuscitation-induced intestinal edema.
- 3% sodium chloride maintenance fluid increased the rate of early primary fascial closure.
- A randomized, control trial is warranted.

New ICU Fluid Resuscitation Strategies for Damage Control Patients

Bryan A Cotton, MD, MPH
Associate Professor of Surgery
Department of Surgery and
The Center for Translational Injury Research
University of Texas Health Science Center
Houston, Texas

When to Close the Abdomen

Words of Wisdom?

John P Hunt MD MPH

LSU Surgery

The Proverbial "Wiseguy"

- I will state the obvious
- I will over-generalize
- I will oversimplify
- I will put forth sweeping, but unsubstantiated conclusions
- I will be hypercritical
- I will tell stories

Objectives

- Lay down "The Facts"
- Leave you with more questions than answers

Damage Control Surgery & Resuscitation Saves Lives

- Definitive lap – 11%(1/9)
- Damage control – 77%(10/13)

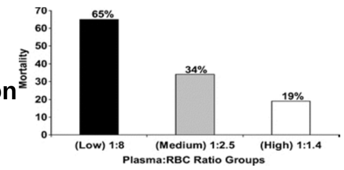
'DAMAGE CONTROL': AN APPROACH FOR IMPROVED SURVIVAL IN EXSANGUINATING PENETRATING ABDOMINAL INJURY

Michael F. Rotondo, MD, C. William Schwab, MD, FACS, Michael D. McGonigal, MD, FACS, Gordon R. Phillips, III, MD, Todd M. Fruchterman, BA, Donald R. Kauder, MD, FACS, Barbara A. Latenser, MD, and Peter A. Angood, MD

Definitive laparotomy (DL) for penetrating abdominal wounding with combined vascular and visceral injury is a difficult surgical challenge. Physiologic derangements such as dilutional coagulopathy, hypothermia, and acidosis often preclude completion of the procedure. "Damage control" (DC), defined as initial control of hemorrhage and contamination followed by intraperitoneal packing and rapid closure, allows for resuscitation to normal physiology in the intensive care unit and subsequent definitive re-exploration. The purpose of the study was to compare the damage control technique with definitive laparotomy. Over a 3 1/2-year period, 46 patients with penetrating abdominal injuries required laparotomy and urgent transfusion of greater than 10 units packed red blood cells for exsanguination. Medical records were retrospectively reviewed for degree and pattern of injury, probability of survival, actual survival, transfusion requirements for the preoperative and postoperative phases, resuscitation and operative times, lowest perioperative temperature, pH, and HCO_3. No significant differences were identified between 22 DL and 24 DC patients and actual survival rates were similar (55% DC vs. 58% DL). However, in a subset of 22 patients with major vascular injury and two or more visceral injuries (maximum injury subset), otherwise similar to the overall group, survival was markedly improved in patients treated with damage control (10 of 13, 77%*) vs. DLM (1 of 9, 11%) (Fisher's exact test, * $p < 0.02$). In preparation for return to the operating room, DC survivors averaged 8.4 units of packed red blood cells transfused and 10.3 units fresh frozen plasma over a mean ICU stay of 31.7 hours. Resolution of coagulopathy (mean prothrombin time/partial thromboplastin time 19.5/70.4 to 13.3/34.9), normalization of acid-base balance (mean pH/HCO_3 7.37/20.6 to 7.42/24.2), and core rewarming (mean 33.2°C to 37.7°C) were achieved. All patients had gastrointestinal procedures at reoperation (mean operative time, 4.3 hours). We conclude that damage control is a promising approach for increased survival in exsanguinating patients with major vascular and multiple visceral penetrating abdominal injuries.

Damage Control Surgery & Resuscitation Saves Lives

- 246 combat casualties
- Massive transfusion
- Mean ISS – 18
- Mortality – 28%



	OR (95%)	P-value
FFP:PRBC	8.6(2.1-35)	0.003
AISHead/Neck	0.76(0.61-0.94)	0.013
AIS Thorax	0.73(0.57-0.92)	0.009
Systolic BP	1.0(0.98-1.01)	0.457
Hemoglobin	1.1(0.91-1.2)	0.501
Base deficit	0.89(0.84-0.95)	0.001

Borgman MA, et al. *J Trauma* 2007;63:805-813

Damage Control Surgery & Resuscitation Saves Lives

- Retrospective review
- 135 Patients
- > 10 units PRBC
- Operative intervention

FFP:PRBC	Mortality	Risk
1:4	87.5%	18.88 (6.32-56.36)
1:1	26.0%	

Duchesne JC, et al. *J Trauma* 2008;65:272-8.

We Create Monsters

- 15-35% non closure rate[1]
- 15% fistula rate[2]
- Intra-abdominal abscess rates 10-70%[3]
- 6-12 months until final reconstruction[4]
- Frequently require TPN, Home health, or extended care

1. Teixeira PGR, et al. 2008;74:891
2. BEE TK, et al . J Trauma 2008;65:337.
3. Morris JA, et al. Ann Surg 1993;217:576
4. Fabian TC, et al. 1994;219:651

Vacuum Dressings Work

- Towel clips, Bogota bags, Silos, Rayon, and zippers are only to be used if you hate the nurses
- Barker dressing, V.A.C., KCI, ABThera, improve closure rates, keep the bed clean, and help manage fluid balance[1,2]

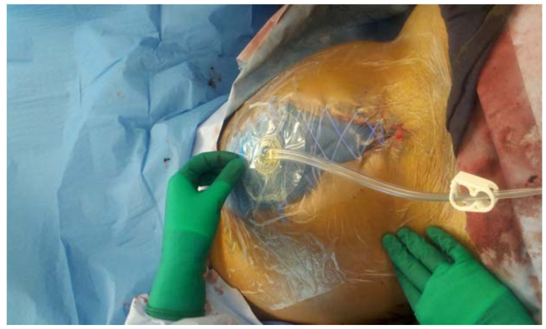
1. Barker et al. J Trauma 2000;48:201
2. Garner et al. Am J Surg 2001;182:630

Abdominal Wall Tension Works



1. Wittmann DH, et al. World J Surg 1990;14:218
2. Smith LA, et al. Am Surg 1997;63:1120
3. Burlew CC, et al. J Trauma 2012;72:235

Abdominal Wall Tension & Vacuum Dressing



Fluid Balance Matters FACTT

- 2x2 factorial design RCT
- Fluid conservative versus liberal management schemes with catheter (Swan vs. CVP)
- 1000 Patients
- Primary end-point was death at 60 days

ARDS Network. NEJM 2006;354:2564-75.

Fluid Balance Matters FACTT

Table 2. Furosemide Dose, Fluid Intake, Fluid Output, and Fluid Balance on Each Day during the Study.*

Day	Furosemide		Fluid Intake		Fluid Output		Fluid Balance	
	Liberal	Conservative	Liberal	Conservative	Liberal	Conservative	Liberal	Conservative
	mg/24 hr (no. of patients)		*ml/24 hr (no. of patients)*		*ml/24 hr (no. of patients)*		*ml/24 hr (no. of patients)*	
1	74.27±7.48 (133)	148.94±8.52 (312)	5029.8±132.98 (485)	4230.5±120.03 (491)	2501.9±73.23 (485)	3043.8±93.90 (491)	2529.5±148.99 (484)	1186.7±151.01 (491)
2	72.46±6.65 (146)	157.35±8.91 (304)	4467.4±136.11 (479)	3590.6±98.45 (480)	2824.5±101.44 (479)	3966.7±115.57 (480)	1642.9±151.71 (479)	−376.1±161.08 (480)
3	65.28±6.49 (140)	166.90±10.01 (269)	3997.1±103.40 (465)	3390.4±85.30 (464)	3060.9±103.23 (465)	3797.3±110.48 (465)	936.12±115.32 (465)	−408.5±135.90 (464)
4	80.74±10.23 (129)	154.25±10.61 (228)	3752.0±102.07 (444)	3430.8±96.49 (437)	3188.1±109.19 (444)	3606.1±113.38 (434)	563.88±100.98 (444)	−165.5±119.92 (434)
5	73.06±8.41 (119)	164.71±12.06 (197)	3825.3±110.62 (424)	3201.1±87.23 (411)	3358.7±115.49 (421)	3444.8±108.98 (408)	483.03±109.98 (421)	−226.3±115.22 (408)
6	58.20±6.68 (106)	158.87±13.45 (165)	3782.8±104.28 (411)	3159.4±88.12 (382)	3334.4±123.99 (411)	3316.9±103.81 (379)	508.04±111.75 (410)	−144.9±110.25 (378)
7	51.03±4.31 (87)	127.86±11.61 (137)	3639.7±93.96 (390)	3226.9±108.18 (355)	3216.8±98.36 (385)	3143.9±100.16 (346)	458.95±106.85 (385)	130.08±118.47 (346)

* Plus-minus values are means ±SE. Numbers in parentheses indicate the number of patients receiving at least one dose of furosemide on that day or the number of patients with a fluid measurement. $P<0.001$ for all comparisons except for fluid intake on day 4 ($P=0.02$) and day 7 ($P=0.004$); fluid output on day 4 ($P=0.008$), day 5 ($P=0.58$), day 6 ($P=0.94$), and day 7 ($P=0.61$); and fluid balance on day 7 ($P=0.04$). Negative fluid balance means that fluid output exceeded fluid intake.

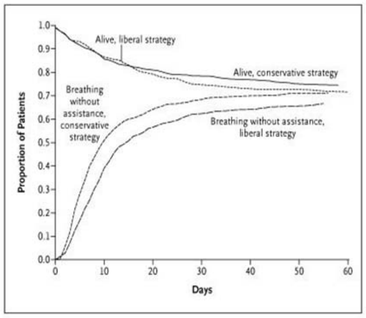
ARDS Network. NEJM 2006;354:2564-75.

Fluid Balance Matters FACTT

Table 3. Main Outcome Variables.*

Outcome	Conservative Strategy	Liberal Strategy	P Value
Death at 60 days (%)	25.5	28.4	0.30
Ventilator-free days from day 1 to day 28†	14.6±0.5	12.1±0.5	<0.001
ICU-free days†			
Days 1 to 7	0.9±0.1	0.6±0.1	<0.001
Days 1 to 28	13.4±0.4	11.2±0.4	<0.001
Organ-failure–free days†‡			
Days 1 to 7			
Cardiovascular failure	3.9±0.1	4.2±0.1	0.04
CNS failure	3.4±0.2	2.9±0.2	0.02
Renal failure	5.5±0.1	5.6±0.1	0.45
Hepatic failure	5.7±0.1	5.5±0.1	0.12
Coagulation abnormalities	5.6±0.1	5.4±0.1	0.23
Days 1 to 28			
Cardiovascular failure	19.0±0.5	19.1±0.4	0.85
CNS failure	18.8±0.5	17.2±0.5	0.03
Renal failure	21.5±0.5	21.2±0.5	0.59
Hepatic failure	22.0±0.4	21.2±0.5	0.18
Coagulation abnormalities	22.0±0.4	21.5±0.4	0.37
Dialysis to day 60			
Patients (%)	10	14	0.06
Days	11.0±1.7	10.9±1.4	0.96

* Plus–minus values are means ±SE. CNS denotes central nervous system.
† This was an a priori secondary outcome.
‡ For this analysis, cardiovascular failure was defined by a systolic blood pressure of 90 mm Hg or less or the need for a vasopressor (in contrast, shock was defined by a mean arterial pressure of less than 60 mm Hg or the need for a vasopressor [except a dose of dopamine of 5 μg per kilogram per minute or less]); a coagulation abnormality was defined by a platelet count of 80,000 per cubic millimeter or less; hepatic failure was defined by a serum bilirubin level of at least 2 mg per deciliter (34 μmol per liter); and renal failure was defined by a serum creatinine level of at least 2 mg per deciliter (177 μmol per liter). We calculated the number of days without organ or system failure by subtracting the number of days with organ failure from the lesser of 28 days or the number of days to death. Organs and systems were considered failure-free after patients were discharged from the hospital.



ARDS Network. NEJM 2006;354:2564-75.

AAST Open Abdomen Study Group

- 11 Level I Centers
- 2010-2011
- Prospectively enrolled
- 572 patients

	OR (95%)	P-value
# of re-explorations	1.34(1.15-1.57)	0.001
Intra-abdominal abscess/sepsis	2.43(1.22-4.83)	0.011
Blood Stream Infection	2.60(1.18-5.70)	0.017
Acute renal failure	2.31(1.19-4.46)	0.013
Enteric Fistula	6.38(1.23-32.86)	0.027
ISS > 15	2.48(1.06-5.85)	0.037

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

Study Design

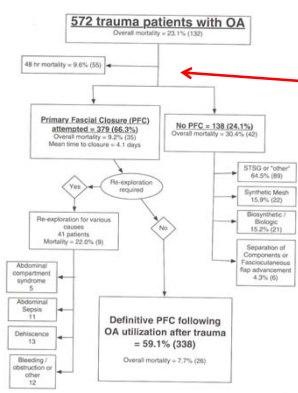


Figure 1. A total of 572 trauma patients with OA.

- Get a real Denominator

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

Study Design

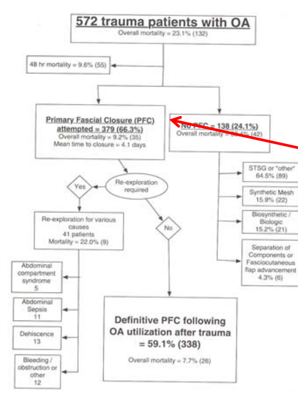


Figure 1. A total of 572 trauma patients with OA.

- Get a real denominator
- Lack of standard variables

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

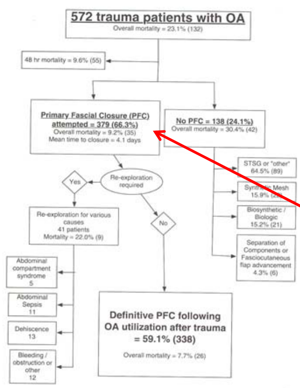


Figure 1. A total of 572 trauma patients with OA.

Study Design

- Get a real denominator
- Lack of standard variables
- Complex decision as a variable

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

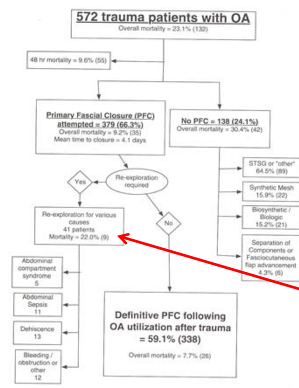


Figure 1. A total of 572 trauma patients with OA.

Study Design

- Get a real denominator
- Lack of standard variables
- Complex decision as a variable
- Define the cost

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

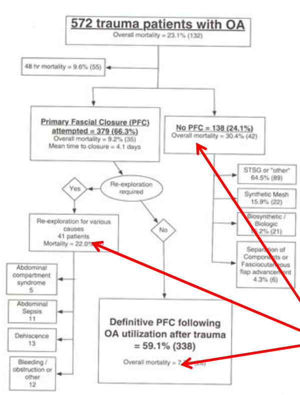


Figure 1. A total of 572 trauma patients with OA.

Study Design

- Get a real denominator
- Lack of standard variables
- Complex decision as a variable
- Define the cost
- Cause specific M & M

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

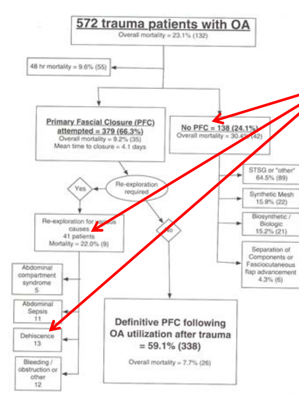


Figure 1. A total of 572 trauma patients with OA.

Study Design

- Use of qualitative methods
- Appreciate the limitations of multiple logistic regression
- Coefficient of Determination for model – r^2 =0.276

Dubose JJ, et al. *J Trauma Acute Care Surg*. 2013;74(1):113

FACTT

Measured intravascular pressure (mm Hg)				MAP <60 mm Hg or a need for any vasopressor (except dopamine ≤5 μg/kg/min); consider correctable causes of shock first	MAP ≥60 mm Hg without vasopressors (except dopamine ≤5 μg/kg/min)			
CVP		PAOP[G]			Average urinary output <0.5 ml/kg/hr		Average urinary output ≥0.5 ml/kg/hr	
Conservative strategy	Liberal strategy	Conservative strategy	Liberal strategy		**Ineffective Circulation** Cardiac index <2.5 liters/min/m² or cold, mottled skin with capillary-refilling time >2 sec	**Effective Circulation** Cardiac index ≥2.5 liters/min/m² or absence of criteria for ineffective circulation	**Ineffective Circulation** Cardiac index <2.5 liters/min/m² or cold, mottled skin with capillary-refilling time >2 sec	**Effective Circulation** Cardiac index ≥2.5 liters/min/m² or absence of criteria for ineffective circulation
Range 1				1 Vasopressor[F] Fluid bolus[F]	3 KVO IV Dobutamine[A] Furosemide[B,1,2,4]	7 KVO IV Furosemide[B,1,2,4]	11 KVO IV Dobutamine[A] Furosemide[B,1,3,4]	15 KVO IV Furosemide[B,1,3,4]
>13	>18	>18	>24					
Range 2					4 KVO IV Dobutamine[A]	8 KVO IV Furosemide[B,1,2,4]	12 KVO IV Dobutamine[A]	16 KVO IV Furosemide[B,1,3,4]
9–13	15–18	13–18	19–24					
Range 3				2 Fluid bolus[F] Vasopressor[F]	5 Fluid bolus[C]	9 Fluid bolus[C]	13 Fluid bolus[C]	17 Liberal KVO IV
4–8	10–14	8–12	14–18					18 Conservative Furosemide[B,1,3,4]
Range 4					6 Fluid bolus[C]	10 Fluid bolus[C]	14 Fluid bolus[C]	19 Liberal fluid bolus
<4	<10	<8	<14					20 Conservative KVO IV

ARDS Network. NEJM 2006;354:2564-75.