

[HOME](#) | [SUBSCRIBE](#) | [CURRENT ISSUE](#) | [PAST ISSUES](#) | [COLLECTIONS](#) | [HELP](#) |[GO](#) [More Options](#)Institution: [UNIVERSITY SYSTEM OF MARYLAND LIBRARIES](#) | [Sign In as Individual](#) | [Contact Subscription Administrator at Your Institution](#) | [FAQ](#)

ORIGINAL ARTICLE

Volume 331:1105-1109

October 27, 1994

Number 17

[Next](#) ▶

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

ABSTRACT

Background Fluid resuscitation may be detrimental when given before bleeding is controlled in patients with trauma. The purpose of this study was to determine the effects of delaying fluid resuscitation until the time of operative intervention in hypotensive patients with penetrating injuries to the torso.

Methods We conducted a prospective trial comparing immediate and delayed fluid resuscitation in 598 adults with penetrating torso injuries who presented with a prehospital systolic blood pressure \leq 90 mm Hg. The study setting was a city with a single centralized system of prehospital emergency care and a single receiving facility for patients with major trauma. Patients assigned to the immediate-resuscitation group received standard fluid resuscitation before they reached the hospital and in the trauma center, and those assigned to the delayed-resuscitation group received intravenous cannulation but no fluid resuscitation until they reached the operating room.

Results Among the 289 patients who received delayed fluid resuscitation, 203 (70 percent) survived and were discharged from the hospital, as compared with 193 of the 309 patients (62 percent) who received immediate fluid resuscitation ($P = 0.04$). The mean estimated intraoperative blood loss was similar in the two groups. Among the 238 patients in the delayed-resuscitation group who survived to the postoperative period, 55 (23 percent) had one or more complications (adult respiratory distress syndrome, sepsis syndrome, acute renal failure, coagulopathy, wound infection, and pneumonia), as compared with 69 of the 227 patients (30 percent) in the immediate-resuscitation group ($P = 0.08$). The duration of hospitalization was shorter in the delayed-resuscitation group.

Conclusions For hypotensive patients with penetrating torso injuries, delay of aggressive fluid resuscitation until operative intervention improves the outcome.

THIS ARTICLE

▶ [Abstract](#)

COMMENTARY

▶ [Letters](#)

TOOLS & SERVICES

- ▶ [Add to Personal Archive](#)
- ▶ [Add to Citation Manager](#)
- ▶ [Notify a Friend](#)
- ▶ [E-mail When Cited](#)

MORE INFORMATION

- ▶ [Find Similar Articles](#)
- ▶ [PubMed Citation](#)

For the past two decades the preoperative approach to hypotensive patients with trauma in North America has included prompt intravenous infusion of isotonic fluids^{1,2,3}. The rationale for this treatment has been to sustain tissue perfusion and vital organ function while diagnostic and therapeutic procedures are performed. This approach was based largely on the demonstration in animals in the 1950s and 1960s^{4,5,6} that isotonic-fluid resuscitation was an important life-sparing component of therapy for severe hypotension due to hemorrhage^{4,5,6}. If perfusion of vital organs was rapidly restored by the intravenous administration of blood, crystalloids, or both, the animals generally survived, whereas untreated animals died or had irreversible organ damage due to ischemia.

On the other hand, others have expressed concern that intravenous volume infusion may be detrimental in the clinical setting if administered before the hemorrhage is surgically controlled^{7,8,9,10,11,12,13}. More recent studies have demonstrated that in uncontrolled hemorrhage, aggressive administration of fluids may disrupt the formation of thrombus, increase bleeding, and decrease survival^{14,15,16,17,18}.

The objective of this study was to test the hypothesis that the survival of hypotensive patients with penetrating injuries to the torso would be improved if fluid resuscitation was restricted until the time of operative intervention. We also determined the effect of delayed fluid resuscitation on intraoperative hemorrhage, the length of hospitalization, and the frequency of postoperative complications.

Methods

Study Subjects

Patients eligible for this study were adults or adolescents (age, ≥ 16 years) with gunshot or stab wounds to the torso who had a systolic blood pressure ≤ 90 mm Hg, including patients with no measurable blood pressure, at the time of the initial on-scene assessment by paramedics from the City of Houston Emergency Medical Services system¹⁹. The torso was delineated superiorly by the upper end of the neck, anteroinferiorly by the inguinal ligaments and symphysis pubis, and posteroinferiorly by the gluteal folds. Pregnant women were not enrolled in the study. All patients within the city limits of Houston who met the entry criteria were transported directly by ground ambulance to the city's only receiving facility for patients with major trauma, Ben Taub General Hospital.

Patients included in the final study analysis were those in whom fluid resuscitation might affect outcome. Part of the prospective study design was to exclude the following from the outcome analysis: patients with a Revised Trauma Score of zero at the scene of the injury, those who also had a fatal gunshot wound to the head, and patients with minor injuries not requiring operative intervention. The paramedics caring for the patients were not aware of these exclusion criteria and treated all hypotensive patients with penetrating torso injuries according to the protocol.

Human-Subjects Review

A policy of waived consent, which adhered to the principle of implied consent, was approved by the institutional review board of Baylor College of Medicine, the Harris County Hospital District, and the City of Houston Emergency Medical Services^{20,21}. This waiver of informed consent followed the guidelines specified by federal regulation²².

Setting

The city of Houston has a population of approximately 2 million. The Houston Fire Department is the sole provider of prehospital emergency medical care within the city limits^{19,23}. The Ben Taub Trauma Center and the emergency medical system are staffed by members of the faculty and house staff of the Department of Surgery at Baylor College

of Medicine.

Study Interventions

All patients enrolled in the study were assigned to one of two groups: the immediate-resuscitation group, in which intravascular fluid resuscitation was given before surgical intervention in both the prehospital and trauma-center settings, or the delayed-resuscitation group, in which intravenous fluid resuscitation was delayed until operative intervention. The operative interventions included thoracotomy at the trauma center, thoracotomy in the operating room, laparotomy, neck exploration, and groin exploration. Patients injured on even-numbered days of the month were enrolled in the immediate-resuscitation group, whereas those injured on odd-numbered days were enrolled in the delayed-resuscitation group. The alternating 24-hour periods corresponded to the 24-hour shifts worked by both the paramedics and the trauma teams. Because there were three rotating teams of paramedics and surgical house staff, assignments to the groups were alternated automatically for both prehospital and hospital staff members. Under the specific circumstances being studied, formal randomization procedures were considered not to be logistically feasible. The alternate-day assignment endorsed by the institutional review board prospectively sets a treatment plan for each patient and thus avoids detrimental delays in care for critically injured patients. Except for the preoperative-fluid variable, all other treatment protocols were identical for the two study groups.

Study Protocol

During the prehospital phase, patients assigned to receive immediate fluid resuscitation were treated with a standard paramedical protocol^{1,2,3} that included endotracheal intubation and assisted ventilation with oxygen when appropriate, rapid transport to the emergency center, and insertion of two or more 14-gauge intravenous catheters in the upper extremities for rapid infusion of isotonic crystalloid (Ringer's acetate solution) en route to the hospital. In accordance with recent recommendations, no patients were treated with antishock garments²⁴. Patients with a systolic blood pressure below 100 mm Hg (as determined by auscultation) on arrival at the emergency center received continued intravenous infusions of crystalloid. When necessary, packed red cells were infused according to standard criteria established by the American College of Surgeons Committee on Trauma²⁵. Patients assigned to the delayed-resuscitation group were cared for in an identical manner with the exception that after the insertion of the intravenous catheters, the catheter lumens were covered with an infusion cap that was then flushed with 1 to 2 ml of 1 percent heparin in normal saline. Any additional peripheral or central venous catheters inserted at the emergency center were kept patent by the infusion of Ringer's acetate solution at a rate of 10 ml per hour. After a patient arrived in the operating room and was placed under general anesthesia, intravenous crystalloid and packed red cells were given as needed, regardless of study-group assignment, to maintain systolic arterial pressure of 100 mm Hg, hematocrit \geq 25 percent, and urinary output \geq 50 ml per hour²⁵. Hetastarch was occasionally given as an additional intravascular volume expander.

Main Measurements and Secondary Outcome Variables

The components of the Revised Trauma Score were determined immediately by paramedics at the scene and at the trauma center by surgical house staff²⁶. The times at which emergency vehicles were dispatched, arrived at the scene, departed from the scene, and arrived at the trauma center were recorded by a computerized dispatch system²³. For the purpose of this study, the response interval was defined as the length of time between the first telephone ring at the public-safety answering point (911 center) and the arrival of the ambulance at the street location^{19,23}. The scene interval was defined as the time between the arrival of the ambulance and its departure from that location. The transport interval was defined as the time between the departure from the scene and ambulance docking at the trauma center. The trauma-center interval was defined as the time from the patient's arrival at the center until the patient was transported to

the operating room (not the preoperative holding area).

Both the 1985 and 1990 versions of the Abbreviated Injury Scale were used to determine scores retrospectively for each patient on the basis of a physical examination, a chart review, operative reports, and autopsy results^{27,28}. A score of 6 on the Abbreviated Injury Scale was considered to indicate a fatal head injury. The probability of survival was calculated from the age, cause of injury, Revised Trauma Score, and Injury Severity Score with the use of established criteria^{26,27}. The Revised Trauma Score uses three physiologic measures to quantitate the physiologic severity of injury: the Glasgow Coma Scale, systolic blood pressure, and respiratory rate. The Revised Trauma Score ranges from 0 (full cardiopulmonary arrest) to 7.84 (a respiratory rate of 10 to 29 per minute, systolic blood pressure of more than 89 mm Hg, and a score on the Glasgow Coma scale of 13 to 15). The Abbreviated Injury Scale is a numerical scoring system for rating organ damage sustained during trauma. The Injury Severity Score (mathematically derived from the Abbreviated Injury Scale) ranges from 1 (an extremely minor injury) to 75 (generally a fatal injury). Blood pressures were measured in the trauma center by nurses who were not part of the study team. Survivors were defined as patients who did not die during hospitalization.

Patients surviving after operation were assessed for six prospectively defined postoperative complications: wound infection, adult respiratory distress syndrome, sepsis syndrome, acute renal failure, coagulopathy, and pneumonia^{29,30,31}.

Statistical Analysis

The a priori sample size was calculated on the assumption that death would occur in 35 percent of patients receiving standard preoperative fluid resuscitation for penetrating torso injuries. On the basis of experimental data and previous clinical experience, an estimated 10 to 15 percent improvement in survival was predicted if fluid resuscitation was delayed until operative intervention^{15,17,24}. With a two-tailed alpha value of 0.05 and a beta value of 0.2, it was determined that the study should continue until approximately 600 patients were enrolled.

Analyses were made on an intention-to-treat basis. Categorical variables were compared with chi-square tests, and continuous variables were compared with the Mann-Whitney U rank-sum test. Continuous variables are expressed as means \pm SD. All P values are two-tailed. The results presented are the final results of a 37-month investigation with one interim analysis³¹. For the final analysis, all P values of less than 0.05 were considered to indicate statistical significance according to the Haybittle-Peto boundary³².

Results

Characteristics of the Patients

During the 37-month study (November 1, 1989, to December 22, 1992), a total of 1069 consecutive patients with hypotension and penetrating injuries to the torso were transported by the Houston Emergency Medical Services system to Ben Taub General Hospital. Of the 1069 patients, 172 (16 percent) had a Revised Trauma Score of zero on initial evaluation by paramedics. Another 299 patients (28 percent) subsequently were found to have minor injuries that did not require thoracotomy, laparotomy, or neck or groin exploration. The numbers of patients with these exclusion factors in each group were very similar.

Among the remaining 598 patients, 309 were enrolled in the immediate-resuscitation group and 289 in the delayed-resuscitation group. The two study groups were well matched in terms of demographic and clinical characteristics (Table 1). Prehospital administration of Ringer's acetate solution was associated with a significant increase in systolic arterial blood pressure by the time of arrival at the emergency center. The initial hemoglobin concentration and platelet

count were significantly lower in the immediate-resuscitation group, whereas the prothrombin and partial-thromboplastin times were longer ([Table 2](#)). However, there were no significant differences between the two groups with respect to the systemic arterial pH or venous serum bicarbonate concentration.

View this table: [Table 1](#). Characteristics of 598 Patients with Penetrating Torso Injuries Who Received Immediate or Delayed Fluid Resuscitation.
[\[in this window\]](#)
[\[in a new window\]](#)

View this table: [Table 2](#). Systemic Arterial Blood Pressure and Laboratory Findings on Arrival at the Trauma Center in Patients with Penetrating Torso Injuries, According to Treatment Group.
[\[in this window\]](#)
[\[in a new window\]](#)

Of the 598 patients, 70 patients died before they reached the operating room and 528 underwent operative intervention - 268 in the immediate-resuscitation group (87 percent) and 260 in the delayed-resuscitation group (90 percent). On arrival in the operating room and before the induction of anesthesia, the groups were similar with respect to systolic and diastolic blood pressures, pH, and venous bicarbonate concentrations ([Table 3](#)). However, as was true for values recorded on arrival at the trauma center, the mean hemoglobin concentration was significantly lower in the immediate-resuscitation group ([Table 3](#)).

View this table: [Table 3](#). Systemic Arterial Blood Pressure, Heart Rate, and Laboratory Findings at the Time of Initial Operative Intervention in Patients with Penetrating Torso Injuries, According to Treatment Group.
[\[in this window\]](#)
[\[in a new window\]](#)

Fluid Volumes Administered

During the prehospital phase of patient care, the volume of Ringer's acetate solution administered in the immediate-resuscitation group averaged 870 ml, as compared with 92 ml in the delayed-resuscitation group ([Table 4](#)). The volumes administered at the trauma center averaged 1608 ml and 283 ml, respectively. The administration of antibiotics and contrast medium as well as the placement of additional intravenous catheters (kept at a minimal flow rate to maintain patency) resulted in the infusion of small volumes of fluid in the delayed-resuscitation group. Rapid intravenous infusions of fluid were initiated inadvertently in 10 patients (4 percent) in the delayed-resuscitation group but were discontinued during the trip to the hospital. In 12 other patients assigned to the delayed-resuscitation group (4 percent), rapid infusions of fluid were transiently administered at the trauma center in violation of the protocol. Except for these 22 patients, fluid was restricted in all patients in the delayed-resuscitation group until their arrival in the operating room, regardless of their clinical condition.

View this table: [Table 4](#). Total Volumes of Fluids Administered to Patients with Penetrating Torso Injuries, According to Treatment Group.
[\[in this window\]](#)
[\[in a new window\]](#)

Among the 528 patients who underwent operation, there was no significant difference in the volume of Ringer's acetate or hetastarch administered to the two groups during surgery ([Table 4](#)). In addition, the patients in both groups received similar amounts of packed red cells, fresh-frozen plasma, platelets, and autologous blood transfusions. However, the mean (\pm SD) rate of fluid administration (delivered in an attempt to maintain a systolic blood pressure of 100 mm Hg) was significantly higher in the immediate-resuscitation group than in the delayed-resuscitation group (117 ± 126 ml per

minute vs. 91 ± 80 ml per minute, $P = 0.008$).

Outcome and Complications

The overall rate of survival was significantly higher in the delayed-resuscitation group than in the immediate-resuscitation group (70 percent vs. 62 percent, $P = 0.04$) ([Table 5](#)). The difference in survival was not altered after adjustment for the prehospital and trauma-center intervals. There was a trend toward increased intraoperative blood loss in the immediateresuscitation group ($P = 0.11$). The patients in the immediate-resuscitation group had significantly longer total hospital stays, but the length of stay in the intensive care unit did not differ significantly between the two groups.

View this table: [Table 5. Outcome of Patients with Penetrating Torso Injuries, According to Treatment Group.](#)

[\[in this window\]](#)

[\[in a new window\]](#)

As expected, all patients excluded from the outcome analysis because of an initial prehospital Revised Trauma Score of zero died. Conversely, all patients subsequently excluded from the analyses because they did not require operative interventions survived.

The frequency of complications in each group was similar ([Table 6](#)). However, there was a trend toward more complications in the immediate-resuscitation group ($P = 0.08$).

View this table: [Table 6. Postoperative Complications in Patients with Penetrating Torso Injuries, According to Treatment Group.](#)

[\[in this window\]](#)

[\[in a new window\]](#)

Discussion

Our study shows that aggressive administration of intravenous fluids to hypotensive patients with penetrating injuries to the torso should be delayed until the time of operative intervention. Evolving studies in animals have provided the probable explanation for a detrimental effect of preoperative fluid administration^{14,15,16,17,18,33,34,35,36,37}. Specifically, fluids given before surgical control of bleeding lead to either accentuation of ongoing hemorrhage or hydraulic disruption of an effective thrombus, followed by a fatal secondary hemorrhage³⁴. In addition, intravenous infusions of crystalloid may promote hemorrhage by diluting coagulation factors¹⁷ and by lowering blood viscosity, thereby decreasing the resistance to flow around an incomplete thrombus³⁶.

The mechanism of the detrimental effect of fluid administration in humans is difficult to ascertain. In our study, a trend toward more intraoperative blood loss was found in the immediate-resuscitation group, but the volume of blood loss could not be measured in the more applicable prehospital and trauma-center phases of management, when control of internal hemorrhage was not attempted.

Nonetheless, other clinical findings are consistent with the hypotheses derived from experiments in animals. The initial mean systolic blood pressure measured at the emergency center was significantly higher in the immediate-resuscitation group. Also, despite the relatively small amount of crystalloid infused in the prehospital setting, the mean hemoglobin concentration at the emergency center was lower in the immediate-resuscitation group, suggesting accentuated bleeding and not just an associated effect of hemodilution. Similarly, the prothrombin and partial-thromboplastin times were

more prolonged in this group. Although these clinical associations of elevated blood pressure, relative hemodilution, and longer clotting times for the group in which the survival rate was lower (the immediate-resuscitation group) do not prove the proposed hypotheses, the findings are compatible with the postulated mechanisms for accentuated or secondary hemorrhage.

Some data have suggested that limited administration of fluids with the use of an extremely low blood-pressure level as an end point (e.g., 40 mm Hg) may help maintain limited tissue perfusion in severely hypotensive animals without the adverse effects of accelerated hemorrhage and the associated increased risk of death^{18,37}. However, patients in this study who had systemic arterial blood pressures below 40 mm Hg were generally pulseless and clinically moribund, so that their chances of survival were small, regardless of treatment. Therefore, statistically sound evidence for infusing fluids in this small cohort of patients is still lacking.

Our results challenge traditional practices that espouse aggressive and universal preoperative intravenous infusion of fluids for patients with trauma and hypotension of presumed hemorrhagic origin^{1,2,3}. Although this study of preoperative fluid resuscitation for hypotensive patients with trauma does not necessarily refute the classic studies cited previously,^{4,5,6} it refutes the broad interpretation and extrapolation of those experiments to all aspects of management of trauma. It is not the value of fluid resuscitation that is currently being debated, but rather the volume, timing, and extent of that resuscitation for certain patients. Although the study results should not be directly extrapolated to all age groups, to hypotensive patients with blunt trauma or severe head injuries, or to the rural trauma care setting, they do suggest the consideration of similar studies in these groups of patients.

We are indebted to all the dispatchers, firefighters, emergency medical technicians, paramedics, physicians, nurses, and ancillary care personnel who constituted the integrated trauma care system of the City of Houston, Ben Taub General Hospital, and Baylor College of Medicine during this study for their dedication and their compliance with the protocol; to Mr. Ken Hall, the project coordinator; to Drs. John C. Sacra and C. Thomas Thompson for their encouragement and advice, which greatly enhanced this study; and to Ms. Nina Meher-Homji, Ms. Madelaine Jackson, and Ms. Lisa Palomo for assistance in the preparation of the manuscript.

Source Information

From the Department of Emergency Services, Saint Francis Hospital, Tulsa, Okla. (W.H.B.); the Cora and Webb Mading Department of Surgery (M.J.W., P.E.P., M.K.A., K.L.M.) and the Department of Medicine (P.E.P.), Baylor College of Medicine, Houston; Ben Taub General Hospital, Houston (M.J.W., P.E.P., K.L.M.); the City of Houston Emergency Medical Services, Houston (P.E.P., V.F.G.); and the Department of Surgery, Section of Trauma, Brooke Army Medical Center, Fort Sam Houston, Tex. (R.R.M.).

Address reprint requests to Dr. Mattox at Baylor College of Medicine, One Baylor Plaza, Houston, TX 77030.

References

1. Shock. In: American College of Surgeons, Committee on Trauma. Advanced trauma life support program for physicians: instructor manual. Chicago: American College of Surgeons, 1993:75-110.
2. Caroline NL. Emergency care in the streets. 2nd ed. Boston: Little, Brown, 1983:57-99.
3. Fowler RL. Shock. In: Campbell JE, ed. Basic trauma life support: advanced prehospital care. 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, 1988:107-19.
4. Wiggers CJ. Physiology of shock. New York: Commonwealth Fund, 1950:121-46.
5. Shires T, Coln D, Carrico J, Lightfoot S. Fluid therapy in hemorrhagic shock. Arch Surg 1964;88:688-693.
6. Dillon J, Lynch LJ Jr, Myers R, Butcher HR Jr, Moyer CA. A bioassay of treatment of hemorrhagic shock. I. The roles of blood, Ringer's solution with lactate, and macromolecules (dextran and hydroxyethyl starch) in the treatment of hemorrhagic shock in the anesthetized dog. Arch Surg 1966;93:537-555. [\[CrossRef\]](#) [\[Medline\]](#)
7. Wangenstein SL, Eddy DM, Ludwig RM. The hydrodynamics of arterial hemorrhage. Surgery 1968;64:912-921. [\[Medline\]](#)
8. Bickell WH. Are victims of injury sometimes victimized by attempts at fluid resuscitation? Ann Emerg Med

- 1993;22:225-226. [\[Medline\]](#)
9. Bickell WH, Shaftan GW, Mattox KL. Intravenous fluid administration and uncontrolled hemorrhage. *J Trauma* 1989;29:409-409. [\[Medline\]](#)
 10. Cannon WB, Fraser J, Cowell EM. The preventive treatment of wound shock. *JAMA* 1918;70:618-621.
 11. Office of the Surgeon General, Department of the Army. *Surgery in World War II: general surgery*. Washington, D.C.: Government Printing Office, 1952:6-17.
 12. Crawford ES. Ruptured abdominal aortic aneurysm. *J Vasc Surg* 1991;13:348-350. [\[CrossRef\]](#)[\[Medline\]](#)
 13. Crawford ES, Hess KR, Cohen ES, Coselli JS, Safi HJ. Ruptured aneurysm of the descending thoracic and thoracoabdominal aorta: analysis according to size and treatment. *Ann Surg* 1991;213:417-425. [\[Medline\]](#)
 14. Shaftan GW, Chiu C-J, Grosz CS, Dennis C. The effect of transfusion and of certain hemodynamic factors on the spontaneous control of arterial hemorrhage. *J Cardiovasc Surg (Torino)* 1964;5:251-256.
 15. Milles G, Koucky CJ, Zacheis HG. Experimental uncontrolled arterial hemorrhage. *Surgery* 1966;60:434-442. [\[Medline\]](#)
 16. Gross D, Landau EH, Assalia A, Krausz MM. Is hypertonic saline resuscitation safe in 'uncontrolled' hemorrhagic shock? *J Trauma* 1988;28:751-756. [\[Medline\]](#)
 17. Bickell WH, Bruttig SP, Millnamow GA, O'Benar J, Wade CE. The detrimental effects of intravenous crystalloid after aortotomy in swine. *Surgery* 1991;110:529-536. [\[Medline\]](#)
 18. Stern SA, Dronen SC, Birrer P, Wang X. Effect of blood pressure on hemorrhage volume and survival in a near-fatal hemorrhage model incorporating a vascular injury. *Ann Emerg Med* 1993;22:155-163. [\[Medline\]](#)
 19. A description of emergency medical services in the city of Houston. Houston: City of Houston Fire Department, 1989, 1990, 1991.
 20. Weigel CJ II. Medicolegal aspects of trauma. In: Moore EE, Mattox KL, Feliciano DV, eds. *Trauma*. 2nd ed. Norwalk, Conn.: Appleton & Lange, 1991:839-46.
 21. Mattox KL, Weigel CJ II. Legal complications. In: Mattox KL, ed. *Complications of trauma*. New York: Churchill Livingstone, 1994:305-12.
 22. Public Health Service Act, Public Law 99-158, 45 C.F.R. Section 46.116, at 9-10 (Nov. 20, 1985, revised June 18, 1991).
 23. Curka PA, Pepe PE, Ginger VF, Sherrard RC, Ivy MV, Zachariah BS. Emergency medical services priority dispatch. *Ann Emerg Med* 1993;22:1688-1695. [\[Medline\]](#)
 24. Mattox KL, Bickell W, Pepe PE, Burch J, Feliciano D. Prospective MAST study in 911 patients. *J Trauma* 1989;29:1104-1112. [\[Medline\]](#)
 25. American College of Surgeons, Committee on Trauma. *Advanced trauma life support program for physicians: instructor manual*. Chicago: American College of Surgeons, 1989.
 26. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the Trauma Score. *J Trauma* 1989;29:623-629. [\[Medline\]](#)
 27. *The Abbreviated Injury Scale 1985 Revision*. Des Plaines, Ill.: American Association for Automotive Medicine, 1985.
 28. *The Abbreviated Injury Scale 1990 Revision*. Des Plaines, Ill.: Association for the Advancement of Automotive Medicine, 1990.
 29. Bone RC, Fisher CJ Jr, Clemmer TP, et al. A controlled clinical trial of high-dose methylprednisolone in the treatment of severe sepsis and septic shock. *N Engl J Med* 1987;317:653-658. [\[Abstract\]](#)
 30. Pepe PE, Hudson LD, Carrico CJ. Early application of positive end-expiratory pressure in patients at risk for the adult respiratory-distress syndrome. *N Engl J Med* 1984;311:281-286. [\[Abstract\]](#)
 31. Martin RR, Bickell WH, Pepe PE, Burch JM, Mattox KL. Prospective evaluation of preoperative fluid resuscitation in hypotensive patients with penetrating truncal injury: a preliminary report. *J Trauma* 1992;33:354-362. [\[Medline\]](#)
 32. O'Brien PC, Shampo MA. Statistical considerations for performing multiple tests in a single experiment: 6. Testing accumulating data repeatedly over time. *Mayo Clin Proc* 1988;63:1245-50.
 33. Bickell WH, Bruttig SP, Wade CE. Hemodynamic response to abdominal aortotomy in the anesthetized swine. *Circ Shock* 1989;28:321-332. [\[Medline\]](#)
 34. Shaftan GW, Chiu CJ, Dennis C, Harris B. Fundamentals of physiologic control of arterial hemorrhage. *Surgery* 1965;58:851-856. [\[Medline\]](#)
 35. Harris BH, Shaftan GW, Herbsman H. Maintenance of cardiac output despite deliberate hypotension. *Surg Forum* 1969;20:31-32. [\[Medline\]](#)
 36. Bickell WH, Bruttig SP, Millnamow GA, O'Benar J, Wade CE. Use of hypertonic saline/dextran versus lactated Ringer's solution as a resuscitation fluid after uncontrolled aortic hemorrhage in anesthetized swine. *Ann Emerg*

Med 1992;21:1077-1085. [\[Medline\]](#)

37. Capone A, Safar P, Tisherman S, Peitzman AB. Treatment of uncontrolled hemorrhagic shock: improved outcome with fluid restriction. *J Trauma* 1993;35:984-984.abstract

Related Letters:

Immediate versus Delayed Fluid Resuscitation in Patients with Trauma

Siegel J. H., Veech R. L., Lessard M. R., Brochu J. G., Brisson J., Carli P. A., de la Coussaye J. E., Riou B., Bickell W. H., Pepe P. E., Mattox K. L.

[Extract](#) | [Full Text](#)

N Engl J Med 1995; 332:681-683, Mar 9, 1995. **Correspondence**

This article has been cited by other articles:

- Meybohm, P., Cavus, E., Bein, B., Steinfath, M., Brand, P.-A., Scholz, J., Dorges, V. (2006). Cerebral metabolism assessed with microdialysis in uncontrolled hemorrhagic shock after penetrating liver trauma.. *Anesth. Analg.* 103: 948-954 [\[Abstract\]](#) [\[Full Text\]](#)
- Covey, D. C. (2006). Combat Orthopaedics: A View From the Trenches. *J Am Acad Orthop Surg* 14: S10-S17 [\[Abstract\]](#) [\[Full Text\]](#)
- Dutton, R. P (2006). Fluid management for trauma; where are we now?. *Contin Educ Anaesth Crit Care Pain* 6: 144-147 [\[Full Text\]](#)
- Dretzke, J., Burls, A., Bayliss, S., Sandercock, J. (2006). The clinical effectiveness of pre-hospital intravenous fluid replacement in trauma patients without head injury: a systematic review. *Trauma* 8: 131-141 [\[Abstract\]](#)
- Goaley, T. J., Dente, C. J., Feliciano, D. V. (2006). Torso vascular trauma at an urban level I trauma center.. *PERSPECT VASC SURG ENDOVASC THER* 18: 102-112 [\[Abstract\]](#)
- Cruz, R. J. Jr, Yada-Langui, M. M., de Figueiredo, L. F. P., Sinosaki, S., e Silva, M. R. (2006). The synergistic effects of pentoxifylline on systemic and regional perfusion after hemorrhage and hypertonic resuscitation.. *Anesth. Analg.* 102: 1518-1524 [\[Abstract\]](#) [\[Full Text\]](#)
- Vincent, J.-L., Fink, M. P., Marini, J. J., Pinsky, M. R., Sibbald, W. J., Singer, M., Suter, P. M., Cook, D., Pepe, P. E., Evans, T. (2006). Intensive care and emergency medicine: progress over the past 25 years.. *Chest* 129: 1061-1067 [\[Abstract\]](#) [\[Full Text\]](#)
- Levett, D., Vercueil, A., Grocott, M. (2006). Resuscitation fluids in trauma 1: why give fluid and how to give it. *Trauma* 8: 47-53 [\[Abstract\]](#)
- Cammarata, G. A. A. M., Weil, M. H., Fries, M., Tang, W., Sun, S., Castillo, C. J. (2006). Buccal capnometry to guide management of massive blood loss. *J. Appl. Physiol.* 100: 304-306 [\[Abstract\]](#) [\[Full Text\]](#)
- (2005). Part 10.7: Cardiac Arrest Associated With Trauma. *Circulation* 112: IV-146-IV-149 [\[Full Text\]](#)
- Stadlbauer, K. H., Wenzel, V., Krismer, A. C., Voelckel, W. G., Lindner, K. H. (2005). Vasopressin During Uncontrolled Hemorrhagic Shock: Less Bleeding Below the Diaphragm, More Perfusion Above. *Anesth. Analg.* 101: 830-832 [\[Full Text\]](#)
- Fries, D., Krismer, A., Klingler, A., Streif, W., Klima, G., Wenzel, V., Haas, T., Innerhofer, P. (2005). Effect of fibrinogen on reversal of dilutional coagulopathy: a porcine model. *Br J Anaesth* 95: 172-177 [\[Abstract\]](#) [\[Full Text\]](#)
- Graham, C A, Parke, T R J (2005). Critical care in the emergency department: shock and circulatory support. *Emerg. Med. J.* 22: 17-21 [\[Abstract\]](#) [\[Full Text\]](#)
- Sukumaran, S, Henry, J M, Beard, D, Lawrenson, R, Gordon, M W G, O'Donnell, J J, Gray, A J (2005). Prehospital trauma management: a national study of paramedic activities. *Emerg. Med. J.* 22: 60-63 [\[Abstract\]](#) [\[Full Text\]](#)
- (2004). Evidence-based Colloid Use in the Critically Ill: American Thoracic Society Consensus Statement. *Am. J. Respir. Crit. Care Med.* 170: 1247-1259 [\[Full Text\]](#)
- Ho, H. C., Chapital, A. D., Yu, M. (2004). Hypothyroidism and Adrenal Insufficiency in Sepsis and Hemorrhagic Shock. *Arch Surg* 139: 1199-1203 [\[Abstract\]](#) [\[Full Text\]](#)
- McAuley, D. J (2004). Trauma in pregnancy: anatomical and physiological considerations. *Trauma* 6: 293-300 [\[Abstract\]](#)

THIS ARTICLE

► [Abstract](#)

COMMENTARY

► [Letters](#)

TOOLS & SERVICES

► [Add to Personal Archive](#)

► [Add to Citation Manager](#)

► [Notify a Friend](#)

► [E-mail When Cited](#)

MORE INFORMATION

► [Find Similar Articles](#)

► [PubMed Citation](#)

- Winslow, R. M., Lohman, J., Malavalli, A., Vandegriff, K. D. (2004). Comparison of PEG-modified albumin and hemoglobin in extreme hemodilution in the rat. *J. Appl. Physiol.* 97: 1527-1534 [\[Abstract\]](#) [\[Full Text\]](#)
- Raedler, C., Voelckel, W. G., Wenzel, V., Krismer, A. C., Schmittinger, C. A., Herff, H., Mayr, V. D., Stadlbauer, K. H., Lindner, K. H., Konigsrainer, A. (2004). Treatment of Uncontrolled Hemorrhagic Shock After Liver Trauma: Fatal Effects of Fluid Resuscitation Versus Improved Outcome After Vasopressin. *Anesth. Analg.* 98: 1759-1766 [\[Abstract\]](#) [\[Full Text\]](#)
- (2003). The Pediatric Emergency Care Applied Research Network (PECARN): Rationale, Development, and First Steps. *Acad. Emerg. Med.* 10: 661-668 [\[Abstract\]](#) [\[Full Text\]](#)
- Rivara, F P (2002). Prevention of injuries to children and adolescents. *Inj. Prev.* 8: iv5-8 [\[Abstract\]](#) [\[Full Text\]](#)
- Lecky, F E (2002). Trauma care in England and Wales: Is this as good as it gets?. *Emerg. Med. J.* 19: 488-489 [\[Full Text\]](#)
- Revell, M, Porter, K, Greaves, I (2002). Fluid resuscitation in prehospital trauma care: a consensus view. *Emerg. Med. J.* 19: 494-498 [\[Abstract\]](#) [\[Full Text\]](#)
- Lee, S. K., Morabito, D., Hemphill, J. C., Erickson, V., Holcroft, J. J., Derugin, N., Knudson, M. M., Manley, G. T. (2002). Small-volume Resuscitation with HBOC-201: Effects on Cardiovascular Parameters and Brain Tissue Oxygen Tension in an Out-of-hospital Model of Hemorrhage in Swine. *Acad. Emerg. Med.* 9: 969-976 [\[Abstract\]](#) [\[Full Text\]](#)
- Innerhofer, P., Fries, D., Margreiter, J., Klingler, A., Kuhbacher, G., Wachter, B., Oswald, E., Salner, E., Frischhut, B., Schobersberger, W. (2002). The Effects of Perioperatively Administered Colloids and Crystalloids on Primary Platelet-Mediated Hemostasis and Clot Formation. *Anesth. Analg.* 95: 858-865 [\[Abstract\]](#) [\[Full Text\]](#)
- Marik, P. E., Varon, J., Trask, T. (2002). Management of Head Trauma*. *Chest* 122: 699-711 [\[Abstract\]](#) [\[Full Text\]](#)
- Holmes, J. F., Sakles, J. C., Lewis, G., Wisner, D. H. (2002). Effects of Delaying Fluid Resuscitation on an Injury to the Systemic Arterial Vasculature. *Acad. Emerg. Med.* 9: 267-274 [\[Abstract\]](#) [\[Full Text\]](#)
- Schreiber, M. A., Aoki, N., Scott, B. G., Beck, J. R. (2002). Determinants of Mortality in Patients With Severe Blunt Head Injury. *Arch Surg* 137: 285-290 [\[Abstract\]](#) [\[Full Text\]](#)
- Revell, M., Porter, K., Greaves, I. (2002). Fluid resuscitation in pre-hospital trauma care: a consensus view. *Trauma* 4: 21-28 [\[Abstract\]](#)
- Alldredge, B. K., Gelb, A. M., Isaacs, S. M., Corry, M. D., Allen, F., Ulrich, S., Gottwald, M. D., O'Neil, N., Neuhaus, J. M., Segal, M. R., Lowenstein, D. H. (2001). A Comparison of Lorazepam, Diazepam, and Placebo for the Treatment of Out-of-Hospital Status Epilepticus. *NEJM* 345: 631-637 [\[Abstract\]](#) [\[Full Text\]](#)
- Mongan, P. D., Capacchione, J., Fontana, J. L., West, S., Bungler, R. (2001). Pyruvate improves cerebral metabolism during hemorrhagic shock. *Am. J. Physiol. Heart Circ. Physiol.* 281: H854-H864 [\[Abstract\]](#) [\[Full Text\]](#)
- Stoneham, J., Riley, B., Brooks, A., Matthews, S. (2001). Recent advances in trauma management. *Trauma* 3: 143-150 [\[Abstract\]](#)
- Foëx, B A (2001). The problem of informed consent in emergency medicine research. *Emerg. Med. J.* 18: 198-204 [\[Abstract\]](#) [\[Full Text\]](#)
- Ellenberg, S. S., Temple, R. (2000). Placebo-Controlled Trials and Active-Control Trials in the Evaluation of New Treatments. Part 2: Practical Issues and Specific Cases. *ANN INTERN MED* 133: 464-470 [\[Abstract\]](#) [\[Full Text\]](#)
- Revell, M. P, Porter, K. M (2000). Pre-hospital fluids - when and how much?. *Trauma* 2: 179-186 [\[Abstract\]](#)
- Hyde, J. A., Walsh, M. S, Graham, T. (2000). Conservative management of penetrating torso trauma. *Trauma* 2: 187-197 [\[Abstract\]](#)
- Cornwell III, E. E., Belzberg, H., Hennigan, K., Maxson, C., Montoya, G., Rosenbluth, A., Velmahos, G. C., Berne, T. C., Demetriades, D. (2000). Emergency Medical Services (EMS) vs Non-EMS Transport of Critically Injured Patients: A Prospective Evaluation. *Arch Surg* 135: 315-319 [\[Abstract\]](#) [\[Full Text\]](#)
- Sloan, E. P., Koenigsberg, M., Gens, D., Cipolle, M., Runge, J., Mallory, M. N., Rodman, G. Jr, for the DCLHb Traumatic Hemorrhagic Shock Study Gr, (1999). Diaspirin Cross-Linked Hemoglobin (DCLHb) in the Treatment of Severe Traumatic Hemorrhagic Shock: A Randomized Controlled Efficacy Trial. *JAMA* 282: 1857-1864 [\[Abstract\]](#) [\[Full Text\]](#)
- Cooke, M. W (1999). How much to do at the accident scene?. *BMJ* 319: 1150-1150 [\[Full Text\]](#)
- Brown, R. (1999). Trauma in pregnancy. *Trauma* 1: 245-253 [\[Abstract\]](#)
- Bozeman, W. P., Gaasch, W. R., Barish, R. A., Scalea, T. M. (1999). Trauma Resuscitation/Critical Care Fellowship for Emergency Physicians: A Necessary Step for the Future of Academic Emergency Medicine.

- Acad. Emerg. Med.* 6: 331-333 [[Abstract](#)] [[Full Text](#)]
- Sutcliffe, A. J (1999). Crystalloids and colloids for volume replacement. *Trauma* 1: 115-123 [[Abstract](#)]
 - Odell, J. A (1999). The trauma patient - critical decision making - when to explore the chest?. *Trauma* 1: 125-131 [[Abstract](#)]
 - Eckstein, M., Alo, K. (1999). The Effect of a Quality Improvement Program on Paramedic On-scene Times for Patients with Penetrating Trauma. *Acad. Emerg. Med.* 6: 191-195 [[Abstract](#)] [[Full Text](#)]
 - O'Connor, R. E., Cone, D. C., De Lorenzo, R. A., Domeier, R. M., Moore, W. E., Taillac, P. P., Verdile, V. P., Zachariah, B. S., Davidson, S. J. (1999). EMS Systems: Foundations for the Future. *Acad. Emerg. Med.* 6: 46-53 [[Abstract](#)] [[Full Text](#)]
 - Driscoll, P, Kent, A (1999). The effect of scene time on survival. *Trauma* 1: 23-30 [[Abstract](#)]
 - Bourguignon, P. R., Shackford, S. R., Shiffer, C., Nichols, P., Nees, A. V. (1998). Delayed Fluid Resuscitation of Head Injury and Uncontrolled Hemorrhagic Shock. *Arch Surg* 133: 390-398 [[Abstract](#)] [[Full Text](#)]
 - Schierhout, G., Roberts, I. (1998). Fluid resuscitation with colloid or crystalloid solutions in critically ill patients: a systematic review of randomised trials. *BMJ* 316: 961-964 [[Abstract](#)] [[Full Text](#)]
 - Meissner, M. H., Chandler, W. C., Nicholls, S. C. (1997). Coagulopathy After Ruptured Abdominal Aortic Aneurysm. *VASC ENDOVASCULAR SURG* 31: 727-736 [[Abstract](#)]
 - Brouhard, B. H. (1997). Fluid and Electrolyte Therapy. *CLIN PEDIATR* 36: 401-402
 - Cooke, M., Hodgetts, T., Smith, R. (1996). Prehospital emergency care. *BMJ* 313: 1220-1221 [[Full Text](#)]
 - Simpson, H. K, Smith, G. B (1996). Survey of paramedic skills in the United Kingdom and Channel Islands. *BMJ* 313: 1052-1053 [[Full Text](#)]
 - Haupt, M. T., Shoemaker, W. C., Haddy, F. J., Simini, B., Gattinoni, L., Brazzi, L., Pesenti, A. (1996). Goal-Oriented Hemodynamic Therapy. *NEJM* 334: 799-800 [[Full Text](#)]
 - Schultz, C. H., Koenig, K. L., Noji, E. K. (1996). A Medical Disaster Response to Reduce Immediate Mortality after an Earthquake. *NEJM* 334: 438-444 [[Full Text](#)]
 - Siegel, J. H., Veech, R. L., Lessard, M. R., Brochu, J. G., Brisson, J., Carli, P. A., de la Coussaye, J. E., Riou, B., Bickell, W. H., Pepe, P. E., Mattox, K. L. (1995). Immediate versus Delayed Fluid Resuscitation in Patients with Trauma. *NEJM* 332: 681-683 [[Full Text](#)]
 - Jacobs, L. M. (1994). Timing of Fluid Resuscitation in Trauma. *NEJM* 331: 1153-1154 [[Full Text](#)]

[HOME](#) | [SUBSCRIBE](#) | [SEARCH](#) | [CURRENT ISSUE](#) | [PAST ISSUES](#) | [COLLECTIONS](#) | [HELP](#)

Comments and questions? Please [contact us](#).

The New England Journal of Medicine is owned, published, and [copyrighted](#) © 2007 [Massachusetts Medical Society](#). All rights reserved.