0022-5282/89/2908-1104$02.00/0
THE JOURNAL OF TRAUMA

Vol. 29, No. 8
Printed in U.S.A.

Prospective MAST Study in 911 Patients

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Nine hundred eleven patients with systolic blood pressures ≤90 mm Hg were randomized to MAST and No-MAST groups, and all taken to a single Level I Trauma Center. Epidemiologic analysis of etiology, age, race, sex, Trauma Scores, and Injury Severity Scores revealed the two groups to be statistically identical. Seven hundred eighty-four patients were analyzed in detail. The principal injury location was thorax in 41%, abdomen in 32%, extremity in 16%, head in 7%, and neck in 4%. In patients with head and extremity wounds, the mortality rate was clearly not a function of MAST use. In the chest, abdomen, and neck, MAST did not improve survival.

Although the total prehospital time was 35.8 + 10.4 minutes for MAST patients and 32.5 ± 10.7 minutes for No-MAST patients, 70% of patients with MAST had prehospital times greater than 30 minutes compared to 55% of the No-MAST patients. When the prehospital time was greater than 30 minutes, 31% of the MAST patients died, compared to 21% of the No-MAST patients. MAST application adversely affected the outcome most significantly for patients with cardiac and thoracic vascular injury. The overall mortality of 31% in the MAST group, compared to 25% in the No-MAST group was statistically significant ($p = 0.05$).

Lower body external pneumatic compression has been promulgated as an attractive means of combating surgical, traumatic, and aviation hypotension since 1907. Inspired by the work of Crile, Gardner, Wangensteen, and Cutler, Kaplan developed a model of antishock trousers at Ft. Rucker, Alabama, which was tested in Viet Nam and which was the prototype for currently used models (12–16, 18, 21–25, 28, 32–37, 54–56, 59). During the 1970's, these garments were commercially produced and widely praised by emergency medical service providers, emergency physicians, surgeons, and even state legislatures (2, 7, 11, 38, 39, 43). The initial Advanced Trauma Life Support course of the American College of Surgeons supported the use of the Military Anti-Shock Trousers (MAST) in the prehospital care of hypotensive trauma patients and indicated that such garments should be routinely available in hospitals designated as trauma centers (4–6). In 1985, reports of 352 hypotensive trauma patients who were prospectively randomized to receive MAST or No-MAST on an alternate day basis were published in the trauma and emergency medicine literature (8, 41, 46–48). Despite receiving enthusiastic endorsement from some and harsh criticism from others, we found no other prospectively randomized evaluation of MAST reported.

This report provides the final results of a continuation study conducted following the original report on 352 patients. A total of 911 patients were enrolled before termination of this continuation study, which specifically examined multiple subpopulations of patients randomized to MAST or No-MAST groups.

METHODS

Patients. Patients included in the study were adult (age >15 years) victims of blunt or penetrating injuries and: 1) presented with a systolic blood pressure of 90 mm Hg or less at the time of initial prehospital assessment by paramedics from the City of Houston EMS, and 2) were transported by ambulance to the Ben Taub General Hospital. Patients were excluded from the study for the following reasons: pregnancy, evisceration, or impaled objects in a body region that would be encompassed by the pneumatic garment.

Protocol. Subjects entered into the study were randomized into the MAST and No-MAST treatment groups by an alternate day assignment. The 24-hour periods of MAST use (or nonuse) corresponded with the 24-hour shifts worked by three rotating paramedic crews and three rotating trauma teams. This randomization method resulted in continuous, automatic alternation of each paramedic crew's treatment plan (MAST vs. No-MAST) as well as the alternation of patients assigned to the rotating surgical teams. The No-MAST group was

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Presented at the Forty-eighth Annual Session of the American Association for the Surgery of Trauma, Newport Beach, California, October 6-8, 1988.

Supported in part by U.S. Army R & D Contract #515-70018.

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...d with a standard paramedic protocol during the prehospital phase, which included endotracheal intubation (when appropriate), attempted placement of 14-gauge intravenous ...ters with crystalloid infusion in the upper extremities, ...apid transport. The assessment included elements of the Trauma Score in the field as well as on arrival at the emergency center. Times of dispatch, scene arrival, scene departure, and trauma center arrival were recorded.

Patients randomized to receive MAST were treated identically to the No-MAST group, with the exception that before intravenous catheter placement, the garment was applied and all bladder compartments simultaneously inflated to full pressure (as evidenced by air escape from the regulator valve or Velcro separation). The MAST used were a commercially available model (MAST III-A, David Clark Company, Worcester, MA). The garments were applied about the legs and abdomen to facilitate the best Velcro alignment with the top of the garment just below the xyphoid. Using standard recommendations, MAST deflation was begun after the patient was hemodynamically stable with a blood pressure of 100 mm Hg or more and the estimated intravascular volume deficit was replaced. In patients with indications for laparotomy, the abdominal bladder of MAST was deflated in the operating room. The leg compartments were kept fully inflated until hemostasis was achieved and the intravascular volume deficit was replaced, at which time the deflation protocol proceeded. Except for the standard removal of MAST, treatment of patients in the emergency center, operating room, and intensive care unit was identical for both the MAST and No-MAST groups. All in-hospital care was under the supervision of the General Surgical Service.

Patient Care Systems. The Houston Fire Department, by law, is the sole first responder for the Houston EMS System. All prehospital care was administered by advanced life support ...ders (paramedics). The only base station for the Houston EMS System is located at the Ben Taub General Hospital, and all prehospital care and base station operations are under the supervision of a single physician (PEP). The Ben Taub General Hospital is a Level I regional trauma facility for Harris County and the Greater Houston area. The Ben Taub Emergency Center, operating rooms, and surgical intensive care unit are staffed by faculty and house staff from the Department of Surgery at Baylor College of Medicine. For analysis purposes, patients were subdivided according to injury type and gross anatomic location of the injury. Types of injuries included gunshot wounds, stab wounds, blunt motorcycle or motor vehicle occupant trauma, blunt auto-pedestrian trauma, and falls. Anatomic subcategories included the thorax, abdomen, neck, head and extremities.

Statistical Analysis. The quantitative variables found to be non-normally distributed by the Anderson-Darling test were compared using the Mann-Whitney U-Test. Chi-square tests, with Yates' correction for small numbers when appropriate, were used for comparison between discrete variables. The Injury Severity Score (ISS) and the probability of survival using the TRISS methodology were calculated for all patients by one individual (KLM). All quantitative variables are expressed as means ±Standard Deviations, significance is assumed, and hence the null hypothesis rejected when the p value is less than 0.05. All p-values are two-tailed. Stratified analysis for adjustment of imbalances between prognostic variables is based on the logistic regression model.

RESULTS

...inical Material. Over a 3½ year period beginning in July, 1983, 911 patients were enrolled in the study. Thirty-eight patients were excluded from outcome analysis due to either transfer to another hospital before definitive therapy or incomplete (or irretrievable) hospital records. Of the remaining 873 patients, 89 were excluded for the following reasons: 1) MAST omitted on patients randomized to the MAST treatment group (N = 66); 2) MAST applied to patients randomized to the No-MAST treatment group (N = 11); 3) One or more pneumatic air bladders deflated in the field because of significant air leaks or inadvertent opening of the air valve(s) (N = 12). With the application of MAST being an additional *active* process and the non-application requiring no such active and conscious efforts, more MAST application "misses" on MAST days than "misses" in the No-MAST group was not surprising.

Independent analysis to include all known information has been made using the 911, 873, and 784 populations. When MAST (or No-MAST) use was on inappropriate days, the patient could logically be put into the overall group receiving the opposite treatment. The 784 population includes only appropriate application (or not) of MAST on appropriate days according to strict protocol adherence.

Although the outcome statistics for the 911 and 873 population were virtually identical to the 784 population, to eliminate bias and to minimize non-acceptance of the data, only the last group (784) was used for the detailed outcome analysis.

Seven hundred eighty-four patients were randomized to the MAST (N = 345) and No-MAST (N = 439) treatment groups. Overall comparison of the demographic factors of age, sex, mechanism of injury, anatomic location of injury, and severity of injury showed no relevant differences between the MAST and No-MAST treatment groups (Tables I & II).

Prehospital and In-hospital Clinical Course. No significant difference was noted in the response times or transport times between the MAST and No-MAST groups (Table III). Injury severity in the MAST and No-MAST groups was not significantly different (Table IV). Prehospital MAST, however, was associated with a significant increase in the scene time. Although not statistically significant, an increased volume of intravenous crystalloid was given to the MAST group in the prehospital phase by the paramedics. Prehospital MAST application did not significantly effect the presenting emer-

TABLE I
Comparison of anatomic location of primary injury between no-MAST and MAST patients

	No-MAST	MAST	Totals
Head	33	21	54
Neck	17	12	29
Thorax	186	134	320
Abdomen	126	124	250
Extremity	73	50	123
Multiple	4	4	8
Totals	439	345	784

TABLE II
Mechanism of injury

	No-MAST	MAST	Totals
GSW	194	178	372
SW	177	130	307
MVA	25	15	40
Auto-pedestrian	14	8	22
Motorcycle	8	4	12
Fall	3	2	5
Other*	18	8	26
Totals	439	345	784

* Combined injury or beating.
p = ns.

TABLE III
Prehospital course for No-MAST and MAST patients

	No-MAST	MAST	p-value
Initial Trauma Scores (in field)	11 ± 5	11 ± 4	ns
EMS response times (minutes)	5.7 ± 3.2	5.7 ± 3.3	ns
Scene times (minutes)	12.6 ± 8.4	16.4 ± 8.6	<0.05
Transport times (minutes)	13.2 ± 8.8	13.7 ± 8.6	ns
Prehospital intravenous fluids (ml)	1,080 ± 650	1,200 ± 760	ns

TABLE IV
Comparison of injury severity for No-MAST and MAST patients

	No-MAST (N = 439)	MAST (N = 345)	p-value
Trauma Score (scene)	11 ± 5	11 ± 4	ns
Trauma Score (EC)	11 ± 6	12 ± 6	ns
Injury Severity Score	19.2 ± 12.8	20.0 ± 12.9	ns
Probability survival (TRISS)	0.749 ± 0.36	0.727 ± 0.39	ns

EC = Emergency Center.
ns = nonsignificant.

TABLE V
Hospital course comparison for No-MAST and MAST patients

	No-MAST (N = 439)	MAST (N = 345)	p-value
Length of stay in ICU (days)	1.9 ± 6.5	3.7 ± 12.5	<0.05
Length of stay in hospital (days)	8.1 ± 16.2	9.7 ± 22.8	ns
Survival	75%	69%	<0.05

gency center Trauma Score (Table V). Length of stay in the intensive care unit was increased in the MAST group because of multiple complications not thought to be associated with MAST use (Table VI). However, total hospital time was not significantly affected.

Overall Survival. Of the 784 patients included in this study, 222 died. The survival rate was greater in the No-MAST group (p = 0.05) (Table V). Analysis of survival by anatomic location failed to demonstrate a specific subgroup which could account for the increased mortality in the MAST group, although patients with

TABLE VI
Comparison of survival by primary anatomic location of injury

	No-MAST	MAST	p-value
Head	45%	33%	ns
Neck	71%	83%	ns
Thorax	68%	58%	0.06
Abdomen	77%	72%	ns
Extremities	100%	96%	ns
Overall	75%	69%	<0.05

TABLE VII
Comparison of survival among patients with a prehospital blood pressure of ≤70 systolic

	No-MAST	MAST	p-value
BP 51 to 70			
Number	96	89	
Survivors	81	65	0.0717
% Survival	84.4%	73.0%	
BP < 50			
Number	72	55	
Survivors	21	21	0.3227
% Survival	29.2%	38.2%	

TABLE VIII
Comparison of patients (including DOA's) with thoracic injury

Total Patients With	No-MAST	MAST	Totals	p-value
1° thorax injury	186	134	320	
Cardiac injury	41 (22.6%)	37 (27.6%)	85	
Thoracic vascular injury	47 (25.2%)	35 (26.1%)	89	
Deaths*	59 (31.7%)	56 (41.8%)	115	0.06
DOA's 1° thoracic injury	11	22	33	0.0028
% DOA's (of thoracic deaths)	5.2%	16.4%		

thoracic injury accounted for the most apparent difference (Table VI). In fact, a consistent overall effect of decreased survival was noted in the MAST treatment subgroups (p = 0.05).

Patients with Prehospital Blood Pressures of 70 mm Hg or less. Three hundred twelve patients had an initial blood pressure in the field of 70 or less (Table VII). For patients with blood pressures of 51 to 70, survival was 11.4% higher in the No-MAST group. In patients with a blood pressure of 50 or less, survival was 9% higher in the MAST group, although the p-value for both of these groups failed to attain significance.

Patients with a Primary Thoracic Injury. In 320 patients, location of the primary injury was in the thorax (Table VIII). A 31.7% mortality was seen in the No-MAST group, compared to a 41.8% mortality in the MAST group (p = 0.006). For patients with thoracic injury in the MAST group, the incidence of prehospital mortality was two times greater.

Patients with Abdominal Injury. For the 250 patients with the primary injury site in the abdomen

MAST provided no advantage from the standpoint of survival. For patients with abdominal injury, neither use of MAST nor level of hypotension affected the final outcome (Table IX). When patients with major abdominal vascular injury were analyzed specifically, a trend toward greater survival again was found in the No-MAST group (63.4% vs. 54.9%) (Table X).

Patients with Blunt Trauma. Ninety patients were victims of nonpenetrating trauma (Table XI). Although the MAST and No-MAST populations in the subgroup were equal with regard to injury severity and treatment, survival rate tended (although not attaining statistical significance) to be greater in the No-MAST group. In addition, patients who were victims of blunt trauma and had MAST applied were dead on arrival 6.6% of the time, compared to 3.3% of the time when MAST were not applied.

Patients Dead on Arrival (DOA). A special group consisted of patients who met the entry criteria in the field but were dead on arrival (DOA) at the emergency center. The injury severity for this group was the same for both study populations (Table XII). Although more patients in the thoracic injury group did not receive MAST, the number of DOA's in this group *doubled* when MAST was applied (Table XIII). Of those with primary thoracic injuries, 16.4% of those with MAST applied were dead on arrival, compared to only 5.2% without MAST (Table XIV). This markedly greater prehospital mortality trend continued to be seen in the patients with thoracic injury and predominantly a cardiac or major thoracic vascular injury (Table XIV). In each of these categories for DOA patients (thoracic vascular and cardiac injuries) there was a *three times greater* prehospital mortality when MAST was applied compared to the No-MAST controls.

Patients with Prehospital Times Greater than 30 Minutes. Prehospital time is defined as the time from dispatch to time of arrival at the emergency room. Four hundred eighty-four patients had total prehospital times of 30 minutes or greater (Table XV). Regardless of the subgroup subjected to analysis, these prolonged prehospital times when MAST was applied resulted in no survival advantage (Table XV).

Logistic Regression Analysis. The influence of

TABLE IX
Survival comparison by initial field BP of patients with major abdominal vascular injury (excluding patients dead on arrival)

	No-MAST	MAST	*p*-value
BP 71 to 90			
Number	43	41	ns
Survivors	27	24	ns
% Survival	62.8%	60%	ns
BP 51 to 70			
Number	29	22	ns
Survivors	16	9	ns
% Survival	55.2%	40.9%	ns
BP <50			
Number	10	6	ns
Survivors	2	1	ns
% Survival	20%	16.6%	ns

TABLE X
Comparison of outcome in patients with abdominal injury

	No-MAST (N = 126)	MAST (N = 124)
Survivors	97	89
% Survival	77%	71.8%
Number of DOA's	3	6
DOA's as % of total number of abdominal injuries	2.4%	4.8%
DOA's as % of abdominal deaths	10.3%	17.1%
Number with major abdominal vascular injury	64%	51%
Survivors in patients with major abdominal vascular injury	40%	28%
Survivors in patients with major vascular injury	63.5%	54.9%

TABLE XI
Comparison of No-MAST and MAST in patients sustaining blunt trauma

	No-MAST (N = 60)	MAST (N = 30)	*p*-value
Trauma Score (scene)	11.3 ± 5.0	11.1 ± 5.3	ns
Trauma Score (EC)	11.7 ± 5.4	12.6 ± 5.1	ns
ISS	19.8 ± 5.08	21.3 ± 14.4	ns
Length of hospital stay (days)	11.4 ± 14.6	14.1 ± 26.5	ns
Survivors	49	21	ns
% Survival	81.7%	70.9%	ns
# of patients DOA	2	2	ns
% DOA deaths of the blunt trauma deaths	3.3%	6.6%	

TABLE XII
Injury severity among 49 patients who were dead on arrival comparing No-MAST and MAST groups*

	No-MAST (N = 18)	MAST (N = 31)	*p*-value
Trauma Score (scene)	3.4 ± 3.9	2.9 ± 2.9	ns
Change in Trauma Score (EC–scene)	−1.8 ± 3.3	−1.8 ± 3.3	ns
Injury Severity Score	31.9 ± 16.7	28.4 ± 11.2	ns

* Transport times: No-MAST = 9.6 ± 6.0; MAST = 11.6 ± 4.7—ns.

TABLE XIII
Location of primary injury among patients who were dead on arrival

	No-MAST	MAST	Totals
Head	3	2	5
Neck	1	1	2
Thorax*	11	22	33
Abdomen	3	6	9
Totals	18	31	49

* Overall, primary thoracic injury occurred in 186 No-MAST and 134 MAST patients.

TABLE XIV
Dead on arrival (DOA) patients with thoracic injury: Comparison of cardiac and thoracic vascular injuries

	No-MAST	MAST	*p*-value
Total # DOA patients with thoracic injury	11	22	<0.0028
(% of total deaths)	(5.2%)	(16.4%)	
DOA patients with cardiac injury	4	11	<0.0198
(% of deaths in patients with cardiac injury)	(8.4%)	(29.7%)	
DOA patients with thoracic vascular injury	4	8	0.055
(% of deaths in patients with thoracic vascular injury)	(7.4%)	(22.8%)	

TABLE XV
Comparison of survival for patients with prehospital times of 30 minutes or greater

	No-MAST	MAST	*p*-value
30–45 minutes			
Number	214	186	ns
Survivors	165	126	ns
% Survival	77.1	67.7	ns
46–60 minutes			
Number	37	32	ns
Survivors	31	24	ns
% Survival	83.8%	75%	ns
>60 minutes	5	10	ns
	5	8	ns
% Survival	100%	80%	ns

TABLE XVI
Prognostic analysis of the risk of death according to the logistic regression model

Progression Factor	*p*-value
Prehospital Trauma Score	<0.001
Change in Trauma Score	<0.001
Injury Severity Score	<0.001
Prehospital MAST application	0.003
Mechanism of injury	0.007
Age	0.016
Sex	ns
Response time	ns
Scene time	ns
Transport time	ns

prognostic variables on survival was assessed for all patients by a stepwise logistic regression model (Table XVI). Trauma Score, change in Trauma Score, Injury Severity Score, mechanism of injury, anatomic location of injury, MAST application, and age were the only independent variables that influenced mortality.

DISCUSSION

To date, we know of no prospective controlled trials that have demonstrated an outcome effectiveness of MAST in prehospital injury management. Still, unqualified support for MAST exists despite published controlled studies showing no benefit to their use (8, 9, 3 41, 46–48). A current extensive literature review b McSwain citing more than 200 references on MAST and including various physiologic responses seen with MAS in both man and experimental animals failed to presen any new data which refuted reports from San Francisc and Houston which have indicated that there is n survival advantage when MAST are applied during th prehospital phase of injury management (43). There hav been a number of controlled laboratory or clinical studie as well as some editorial comments which demonstrat either no value or hazards when MAST is applied (1 17, 20, 26, 27, 30, 31, 42, 49, 52, 44, 60).

In a national survey recently conducted by the Texa Emergency Medical Services Information System of th Texas Health Department, it was found that of the 85% of the states responding, MAST was required or recom mended in 65% (40). This widespread legislative mandat continues, despite the fact that controlled, randomize data repeatedly demonstrate *no advantage or benefit* t MAST use. MAST use continues even though medica devices, old and new alike, are coming under sever scrutiny from the Federal Drug Administration in re sponse to the Medical Device Amendments of 1976 (45).

Of prime consideration in analyzing and interpretin data on the 784 hypotensive trauma patients was assur ing that the study populations were identical. One con cern is that MAST "misses" occurred on days when hypotensive patients were supposed to receive MAST As a result, these MAST-misses were eliminated entirely from the outcome analysis. Therefore, it was mandatory that the MAST and No-MAST populations used in the analysis remained statistically identical. The demo graphic and other comparison data from both study and control groups were virtually identical, validating the comparison. All other prehospital, emergency center operating room, intensive care unit, and other care wa identical for both groups, as well.

Insufficient numbers and/or deaths of patients with head, neck, and extremity injury precluded any signifi cant analysis. In fact, mortality among the hypotensive patients with extremity injuries was nonexistent, excep for two patients in the MAST group with severe groi injury. The issues, therefore, relate to the value of MAS for chest, abdominal, and truncal vascular injuries.

A cited criticism of the initial report from this insti tution on the efficacy of MAST was that it did no include patients with prolonged prehospital times o victims of nonpenetrating trauma. We know of no con trolled studies concerning outcome for prehospital time greater than 30 minutes, although supporters of MAS contend that this "might be" an area where MAST coul be useful (2, 3, 57, 58). This 30-minute limit is not a unreasonable period of time to evaluate. The averag prehospital time for rural Texas EMS systems is 37. minutes vs. 33.8 minutes for urban Texas EMS system (ns) (19). As rural Texas is not unlike rural area

roughout the United States, an analysis of the effect of MAST on prehospital times of more than 30 minutes would help to address this question. Indeed, of the 911 population group, 457 of the patients had prehospital times of 30 minutes or greater, yet MAST application did not improve the chances of survival for patients with either short or long prehospital times. Using the logistic regression model, prehospital time did *not* have any prognostic value.

Experimental models of "controlled" or "fixed" hemorrhagic shock have suggested that MAST application in patients with abdominal vascular injury improves survival (1, 5, 7, 16, 36, 37, 52, 54–56). However, these animal models in which the bleeding is halted after a certain point have led to the erroneous conclusion that MAST application will increase the chances of survival. In patients with dynamic, *uncontrolled* hemorrhage in the abdomen, including those with ruptured and leaking abdominal aortic aneurysms, virtually all of the clinical reports have been case reports (11, 29, 50, 53).

The data presented in this current study would not only support the contention that such practice is of *no advantage*, but that it also may indeed be harmful. Speculations as to the reasons for these observations include: 1) increase in the scene time required for MAST application, 2) increase in the cardiac afterload and therefore increased cardiac workload, and 3) an increased tendency to secondary exsanguinating hemorrhage associated as with increasing blood pressure in the patient with uncontrolled hemorrhage. Increasing the cardiac afterload and the blood pressure before intraoperative proximal and distal control in a patient with an uncontrolled abdominal aortic vascular leak actually may increase the rate of exsanguinating hemorrhage. The application of a vascular clamp below or distal to an area of arterial hemorrhage is foreign to the most primitive of vascular surgery principles.

The literature also suggests that the application of MAST causes prehospital elevation of blood pressure and increases the number of patients surviving long enough to reach a trauma surgeon for appropriate treatment. However, the most condemning data in this report were from patients with thoracic injuries (especially cardiac or thoracic vascular) when relating the contribution of MAST to the chances of dying before arrival at the trauma center. A *threefold* increase in the number of dead on arrival (DOA) patients was seen when MAST was applied. It is possible that the application of MAST and the subsequent elevation of blood pressure resulting from the increase in peripheral vascular resistance may actually cause rebleeding or increase the rate of bleeding from a precariously tamponaded or clotted injury, suddenly creating a fatal prehospital situation.

Although there may be speculation as to the physiologic and logistic explanations to the data herein reported, several incontrovertible observations are made. Numerous groupings, subgroupings, and eliminations have been made in attempt to elucidate bias in the sampling or the results. Regardless of the statistical technique or the method of grouping, the conclusions remain the same:

1) MAST application does not significantly increase the length of total prehospital time;

2) MAST application does increase the blood pressure;

3) MAST application does not favorably decrease the length of time in the emergency room, operating room, or hospital.

4) When MAST was applied, an overall increased mortality was seen for all patients;

5) Patients with prehospital time of greater than 30 minutes and MAST application did *not* have a better survival rate;

6) Patients with thoracic injury (including cardiac and major thoracic vascular) had a greater chance of dying before arrival at the hospital (DOA) if MAST was applied;

7) Patients with major abdominal vascular injury did *not* have a better overall survival rate nor did they have a better chance of reaching the trauma surgeon alive if MAST was applied;

8) Using a logistic regression model, MAST application significantly contributed to chance of dying ($p = 0.003$) and was a greater prognostic indicator (of death) than mechanism of injury or age.

This study raises serious questions relating to the logic that raising the blood pressure in the prehospital time period is always a worthy objective. Even McSwain has suggested on at least two occasions that prehospital reversal of moderate hypotension may not necessarily be beneficial (43, 44). Teleologically, there may be a group of hypotensive patients in whom a stable blood pressure between 70 and 90 may actually be more conducive to survival. A rise in blood pressure before achieving a means of controlling the internal hemorrhage may result in loss of the protective hematoma and secondary exsanguinating hemorrhage. Additionally, hemodilution and hypothermia adversely affect clotting mechanisms and perhaps oxygen transport. Increased harmful mediators and free oxygen radicals may develop because of iatrogenic and artificial interventions before optimal surgical control can be achieved. As a result of this study and the conclusions revealed, the pneumatic antishock garment is no longer used on the ambulances of the Houston Fire Department, and no garments of this type are stocked in the Emergency Center of Ben Taub General Hospital.

Acknowledgments

This very large, comprehensive, and quality-controlled study was made possible because of the efforts and energies of many individuals: the EMT's and paramedics of the Houston Fire Department Ambulance Division, one of the most cooperative and dependable groups of individuals with whom it has ever been our privilege to work; the general and thoracic surgery residents of Baylor College of Medicine, whose long hours of diligent work and skill afford our patients the best of care; and

Doctors Mark Bailey, C. Thomas Black, William Dedo, and Charles Wyatt, who spent countless hours collecting data. A special thanks, also, to Mary K. Allen for editorial assistance in preparation of this manuscript.

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DISCUSSION

DR. KIMBALL MAULL (Knoxville, Tennessee): I'd like to thank the Association for the privilege, and indeed it is a privilege, to discuss this controversial paper. I'd also like to thank Doctor Mattox for sending me all three different copies of his manuscript.

Many of you in this room were here some years ago and will vividly recall the author standing before us and condemning MAST trousers as, and I quote, "a tool of the devil."

Are we to believe that this same individual would devise an unbiased experimental protocol to study the effectiveness of MAST, and to gather data therefrom in an unbiased way, review it without bias, submit it to unbiased statistical evaluation, and draw unbiased conclusions, all without regard to having to eat his words publicly?

Or have Doctor Mattox and his colleagues gambled by initiating a tight and well-considered protocol that assures data that are reliable and significant in both the clinical and epidemiologic sense, such that the data, regardless of conclusions, would be difficult to refute?

With apologies to the pro-MAST members of the audience in my judgment he has done just that. His study is sound, and, notwithstanding the limitations of prehospital data collection, is well devised in a prospective manner. This does not mean that I or that we should agree with all of the conclusions in this report.

Perhaps Dr. Mattox and his co-authors have taken a broad swipe at MAST condemnation, broader than is justified from the data, yet there are a number of important points that I would like to recount to you.

The first point is that MAST in an urban setting with predominantly penetrating trauma and short transport times is of no value and may be harmful. Second, MAST in an urban setting with predominantly penetrating trauma and short transport times is contraindicated in patients with thoracic trauma.

Third, MAST in a setting with predominantly penetrating trauma and transport times that exceed 30 minutes, does not offer any clear advantage over patients transported without the MAST garment.

I have a number of questions that I would like you to address in your closing remarks, and I'm sure there are other discussants to follow. First, did the increased intravenous fluid volume infused in the MAST group reflect greater efficiency in starting IV fluids? If so, would this support at least a theoretical advantage of having the device available for field use?

Second, in looking carefully at your data, I noted the following features: the ISS was greater or higher in the MAST group, and the probability of survival was lower in the MAST group. You state that there was a statistically significant difference between the no-MAST and the MAST groups. My question to you is: Since the MAST group had a lower predicted survival by the TRISS methodology, was there a statistically significant difference in mortality between the MAST group and the predicted mortality by TRISS?

One of the few, perhaps the only, category where MAST appeared to be beneficial was in patients with a field systolic blood pressure of less than 50 mm Hg. In this group, survival favored MAST 38% to 29%. My question to you is: did you break this group down further into blunt versus penetrating trauma to look at whether the combination of profound hypotension in blunt trauma could actually identify a subset where MAST may be helpful?

In the manuscript, you state that there were a number of independent variables that affected outcome, one of which was change in Trauma Score. Since an improvement in Trauma Score was seen fairly consistently in the MAST group who had a lower survival, would you have us believe that higher Trauma Scores upon arrival at the hospital causes higher mortality?

In your thoracic trauma group, were there any patients with diaphragmatic lacerations? In our laboratory we demonstrated in swine with surgically created diphragmatic tears that MAST was in fact lethal. Any clinical data in your data to support this point?

And last, MAST in a setting with predominantly blunt trauma, profound hypotension, and long transport times needs to be studied in the same manner that you've done.

Despite the fact that you've pulled the MAST off your ambulances and out of your hospital in Houston, and made that recommendation in the manuscript, it is my judgment that it's a little premature for the rest of us to do the same.

DR. JOSEPH CIVETTA (Miami, Florida): As someone who was one of the early investigators and perhaps enthusiasts in the use of MAST, I would not be at all disheartened to discard a piece of equipment or an intervention that I used to "believe in." In fact, the list of interventions I've discarded over the years is probably longer than the list I use. But before we really discard it, I find a couple of problems in this paper and the preceding studies that I've examined once they were printed.

In the earlier paper—and, of course, there are no blood pressure data in this one, and so it is hard to tell—but there is no increase in blood pressure in the MAST-treated patients in Houston. Now, I don't understand that, because the one thing that everyone else seems to be able to accomplish with MAST application is a marked increase in blood pressure.

For instance, in our patients who had no blood pressure and who were unconscious in the field, when the MAST was applied, the patients woke up and had a systolic blood pressure of about 80, and in our group, 12 of those 13 original patients survived.

Now, these data are different from those reported by the Houston group. I have noticed over the years that the number of patients who arrive at the hospital with a MAST correctly inflated is decreasing. I wonder if one of the reasons that accounts for the failure to improve outcome is that the MAST has not achieved the effect for which it was designed. If blood pressure is not dramatically increased as it used to be, and perhaps has never been increased in Houston, then how can it possibly have an effect of improving survival if the two are to be related?

So my principal question is: what were the blood pressures before and after MAST inflation in Houston in this study? In the previous study, there was no difference. Second, I think it is interesting that the primary concern that we expressed, I guess it must be about 15 years ago, was that MAST should not be used in thoracic injuries, and its bothersome to see that it has been used in these situations and, in fact, that the mortality rate seems to be higher.

DR. NORMAN MCSWAIN, JR. (New Orleans, Louisiana): I noticed that the title of Doctor Mattox's paper stated that this

was "the final report," but yet he indicated to us another revision of the data would be forthcoming, so I wonder, is this article really the final report or is there more to come?

There were significantly longer prehospital times in the MAST group, but yet since we know that MAST application, when done correctly, requires 1 minute, does this mean that the Houston EMT-Ps were not properly trained in the use, or were there more severe injuries in this group that required longer application, or extrication was longer? It would be helpful if Doctor Mattox could explain this difference.

The complication rate was also greater in the MAST group, but Doctor Mattox said this was not associated with MAST use, so that might also indicate another difference in the two groups, despite the large number of patients.

Interestingly enough, the number of patients came out to exactly 911, the magic telephone number. Was this planned or was there some other reason to stop the study exactly on this number?

Review of the literature reveals that all patients who have been studied with intra-abdominal or retroperitoneal hemorrhage demonstrate improved survival, although these were not randomized studies. One of the most outstanding of such papers on pelvic injuries was by our Secretary-Treasurer. There have been multiple studies on animals that are randomized which also indicate improved survival. The latest study by Åberg, which was reported a couple of months ago in the *Journal of Trauma*, is characteristic of prospective randomized studies which show improved survival with PASG.

Obviously, this Association believes that animal studies are important, as by the number of animal papers that we've had the opportunity to see at this meeting. Doctor Mattox, how do you reconcile the difference?

There are also some papers that are beginning to show that uncontrolled hemorrhage with increasing blood pressure is bad, which is one of the important points that Doctor Mattox has pointed out to us. I raise the question then, as did he, are we resuscitating patients appropriately when we raise blood pressure? As Doctor Civetta has pointed out, improved blood pressure would increase the hemorrhage in chest injuries. He listed this as a contraindication with his original work on the PASG. Almost every paper in the literature which discusses resuscitation by any means, however, uses improved blood pressure as an important factor. In the Houston study, Doctor Mattox questions if this is correct. I'm not sure I understand the true role of blood pressure, either. Uncontrolled hemorrhage is bad. Since PASG controls intra-abdominal and pelvic hemorrhage and improves blood pressure, these patients should do better with PASG than without. Doctor Mattox, should we quit resuscitating patients based on blood pressure until they are in the OR and hemorrhage has been controlled?

DR. HOWARD R. CHAMPION (Washington, D. C.): I'd like to congratulate Doctor Mattox who, in the face of continued critical onslaught, has attempted to provide us with scientific underpinnings for his opinions.

I would like to ask him if he has any hypotheses to add to those opinions with regard to the basis for the deleterious effects that he observed with this instrument of evil.

DR. C. GENE CAYTEN (Bronx, NY): I wanted to ask whether you had enough of a sample size to look at patients with pelvic fractures with and without MAST?

DR. LENWORTH M. JACOBS, JR. (Hartford, CT): I appreciated this paper and the fact that its prospective is laudable. I have one methodologic question. The study was an alternate-day prospective trial. The author is well known for his intimidating views on the subject. He is also well known for his advocacy of medical control.

One would expect that the number of MAST and no-MAST on an alternate-day sample should be equal, and yet no-MAST is 215 and MAST is 136. I wonder if the Mattox intimidation factor for no-MAST suit is a factor which should be added to in Houston EMS.

DR. KENNETH L. MATTOX (Closing): Mr. Chairman, I find some of the overtones in the discussion confusing and disturbing. It was 3 years ago that we shared the original preliminary data with this Association with a very carefully structured, controlled, randomized prospective clinical study. To the verbal skeptics, some of whom we have heard from again today, we requested to see contrary outcome data from their studies.

We have held the data that you saw today for 2 years and didn't even whisper the specifics of its existence so that we would not prejudice IRBs against your ability to obtain randomization. However, no other similar study in humans has emerged.

Furthermore, among the more than 700 authors in the titles of more than 250 articles on MAST are but a handful of AAST members. The closest to science some of our membership has come on this subject is to be cited in the 1988 McSwain review article, as giving to McSwain personal communication. The guantlet was thrown down, and you didn't pick it up.

Additionally, in this audience is a large number of our membership who have become closet believers. For a variety of reasons, several cities, including Denver and Milwaukee, are currently routinely not using MAST in the field. It is time to either come out of the closet or produce competing efficacy data.

Many of the specific questions can be answered simply. MAST application did increase the ability to start IV's in the field. The ISS's were statistically identical between groups. There was not a statistical analytic comparison of the overall TRISS-predicted survival, as the components of the TRISS were individually analyzed. The population cohorts were statistically identical. MAST application *did* result in an elevation in the blood pressure to the same degree as seen in the No-MAST patients. There were no patients with diaphragmatic tears in either group. Those with diaphragmatic injury coming into our trauma center during the study time were not hypotensive at the time of paramedic arrival in the field. Patients with various grades of pelvic fractures were too few in each group to warrant a separate analysis. As stated in the manuscript, all of the medical supervision in the field was under the direction of Doctor Paul Pepe. Any implied or suggested discipline only served to assure an attention to detail rather than an implied description of a new syndrome of an intimidation factor.

The reasons for the statistically longer ICU stay for the MAST patients remains unexplained. It would be tempting to speculate that MAST application contributed to the increased production of derogatory mediators, but I will refrain from such speculation for fear of being criticized as describing as yet another complication of MAST.

Mr. Chairman, I am deeply appreciative for the comments and questions of all the discussants, which provided the opportunity to further clarify the data from this study, and hopefully will forever close the books on this final report on MAST.