Blunt Trauma Resuscitation

The Old Can Respond

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Hypothesis: Old and young trauma patients are capable of hyperdynamic response during standardized shock resuscitation.

Design: The responses of old and young trauma patients resuscitated using a standardized protocol are compared in an inception cohort study. A standardized resuscitation protocol was used to attain and maintain an oxygen delivery index of 600 mL/min·m^2 or greater ($DO_2I \geq 600$) for the first 24 hours in the intensive care unit. Interventions, responses, and outcomes for old (≥65 years) and young (<65 years) patients are described. Data were analyzed using analysis of variance, the χ^2 test, and the *t* test; $P<.05$ was considered significant.

Setting: A 20-bed shock trauma intensive care unit in a regional level I trauma center.

Patients: Patients at high risk of postinjury multiple organ failure, ie, major organ or vascular injury and/or skeletal fractures, initial base deficit of 6 mEq/L or greater, need for 6 units or more of packed red blood cells in the first 12 hours, or age of 65 years or older with any 2 previous criteria.

Interventions: Pulmonary artery catheter, crystalloid fluid infusion, packed red blood cell transfusion, and moderate inotrope support, as needed in that sequence, to attain $DO_2I \geq 600$.

Main Outcome Measures: Intensive care unit length of stay and survival.

Results: During 19 months ending June 1999, 12 old patients (58% male; age, 76 ± 2 years [mean ± SEM] [$P<.001$]; Injury Severity Score, 20 ± 2 [$P=.02$]) and 54 young patients (61% male; age, 37 ± 2 years; Injury Severity Score, 32 ± 2) were resuscitated. Initially, for old patients (cardiac index, 2.0 ± 0.2 L/min·m^2) and for young patients (cardiac index, 3.0 ± 0.2 L/min·m^2; $P=.01$), 24-hour volumes were as follows: 16 ± 3 L of crystalloid and 12 ± 3 units of packed red blood cells for the old patients and 21 ± 2 L of crystalloid and 19 ± 2 units of packed red blood cells for the young patients. For old patients, 9 (75%) attained $DO_2I \geq 600$, and 11 (92%) survived 7 or more days and 5 (42%) 30 or more days. For young patients, 45 (83%) attained the DO_2I goal, and 48 (89%) survived 30 or more days. Intensive care unit length of stay was 25 ± 9 days for the old patients and 23 ± 2 days for the young patients.

Conclusions: Elderly patients have initially depressed cardiac index but generate hyperdynamic response. Although ultimate outcome is poorer than in the younger cohort, resuscitation is not futile.

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RESUSCITATION of traumatic shock is a frequent management issue in regional trauma centers. Although effective shock resuscitation is an important component of early care in the intensive care unit (ICU), specific resuscitation methods are controversial, which leads to variability in care, confusion of bedside personnel, and delayed interventions. Based on literature evidence and expert opinion, our trauma surgeon–directed working group therefore developed a standardized, data-driven protocol for shock resuscitation.

The elderly trauma patient presents the dilemma of whether to use presumptive pulmonary artery catheterization to guide early shock resuscitation vs a less aggressive "wait and see" approach that could prolong shock and its consequences. We have applied our standardized resuscitation protocol to all patients who have met criteria. Our purpose is to compare the response of old and young blunt trauma patients to this standardized process to determine if there is a difference in the response of the elderly blunt trauma patient.

PATIENTS AND METHODS

We describe the response to a standardized resuscitation process in an inception cohort study. The study patients were admitted to the Shock Trauma Intensive Care Unit (STICU) of Memorial Hermann Hospital, Houston, Tex, a level I regional trauma center and teaching affiliate of the University of Texas–Houston Medical School that serves the greater Houston (southeastern Texas) area, which comprises a population of 4 million. During a 19-month period ending June 1999, Memorial Hermann Hospital had 8269 trauma registry patients, of whom 1398 were admitted to the STICU. Sixty-six (5% of STICU admissions) met criteria to be resuscitated by our standardized protocol. This early presumptive management is centered on the diagnosis and treatment of traumatic shock, based on the consistent epidemiologic finding that shock is the predominant potentially treatable early risk factor for postinjury multiple organ failure (MOF).[1-4]

Risk of MOF is objectively defined by (1) specific injuries (flail chest, ≥2 abdominal organ injuries, major vascular injury, complex pelvic fracture, ≥2 long bone fractures), (2) base deficit (BD) of 6 mEq/L or greater, and (3) need for a transfusion of 6 units or more of packed red blood cells (PRBC) or (4) a trauma patient 65 years or older with any 2 of the previous criteria. Patients with these criteria who also have incurred severe brain injury (defined as Glasgow Coma Scale score ≤8 in the STICU and brain computed tomographic scan abnormalities) are not resuscitated by protocol, unless the patient's brain injury has been assessed by the attending neurosurgeon to be at low risk of worsening cerebral edema with volume loading. On STICU admission, patients with these criteria presumptively receive pulmonary artery and peripheral artery catheters that are used to guide resuscitation according to the standardized protocol during the first 24 hours in the ICU.

Resuscitation is implemented as a standardized, data-driven process that is tailored to the needs of the individual patient (**Figure 1**). A pulmonary artery catheter, with continuous cardiac output and mixed venous hemoglobin oxygen saturation monitoring capability, and a gastric tonometer-sump catheter (Datex-Ohmeda Inc, Helsinki, Finland), with gastric mucosal interstitial P_{CO_2} (P_{gCO_2}) monitoring capability, are placed. Volume resuscitation with crystalloid fluid and blood is undertaken. The immediate goal is to attain and maintain an oxygen delivery index of at least 600 mL/min · m^2 ($DO_2I \geq 600$). If DO_2I less than 600 mL/min · m^2 ($DO_2I < 600$) is determined, then a hemoglobin concentration (Hb) less than 100 g/L or less than 120 g/L for patients 65 years or older and/or pulmonary artery wedge pressure (PAWP) less than 15 mm Hg prompt PRBC transfusion and/or lactated Ringer solution volume loading. If $DO_2I < 600$ persists, then optimal cardiac index (CI)–PAWP combination is determined using incremental bolus infusion ("Starling curve"). Mild to moderate inotropic support of cardiac contractility and/or vasopressor support is the final therapy used to attain and maintain $DO_2I \geq 600$. If $DO_2I \geq 600$ is determined, then no intervention is made for resuscitation, standard ICU monitoring proceeds, and DO_2I is determined again 4 hours later or when hemodynamic instability is encountered. Indices of perfusion deficit, BD, and serum lactate concentration (lactate), also obtained at 4-hour intervals, and P_{gCO_2}, a continuous monitor, are used by the supervising attending physician as secondary indices of resuscitation to decide how aggressively to pursue therapeutic resuscitative options. $DO_2I \geq 600$ within 24 hours of admission to the ICU and sustained for at least the last 4-hour interval is our definition that the patient has attained the resuscitation DO_2I goal.

This goal-directed protocol has been described previously.[2] A standardized decision-making process has been implemented that is applied to all severe trauma patients with these criteria using a detailed worksheet and flowchart algorithm that is provided to the bedside clinician team for each patient. The essential diagnostic data, ie, Hb, CI, arterial oxygen saturation, PAWP, BD, lactate, and P_{gCO_2}, are used for decision making in real time, and clearly described interventions, ie, lactated Ringer solution bolus, PRBC transfusion, and dobutamine and norepinephrine infusion, are used in a defined sequence. Both diagnostic data and interventions are recorded in real time for review.

Data were obtained prospectively during the protocol resuscitation process. Retrospectively, the resuscitation response of patients 65 years and older were compared with patients younger than 65 years. The resuscitation variables DO_2I, CI, Hb, PAWP, systemic vascular resistance index (SVRI), BD, lactate, P_{gCO_2}, and blood and fluid volumes were compared during the resuscitation process. Injury Severity Score (ISS), survival, incidence of MOF, ICU length of stay, and duration of mechanical ventilatory support were also compared. Multiple organ failure was defined using a standard score for organ dysfunction occurring after 48 hours of hospital admission.[4] Data are presented as mean ± SEM in the text and figures. Data were analyzed using analysis of variance, the χ^2 test, and the *t* test. A difference between or within the old and young groups with $P < .05$ was considered significant.

RESULTS

During the 19-month study period, 66 trauma patients were admitted with criteria for our shock resuscitation protocol and were resuscitated using the standardized 24-hour process. The mean age was 44 ± 2 years (range, 17-87 years), 41 (62%) were male, and 59 (89%) involved blunt mechanisms of injury. Of the 59 blunt mechanisms, 52 (88%) were motor vehicle or motorcycle crashes, 3 (5%) were automobile-pedestrian collisions, and 4 (7%) were other. Of the 7 penetrating mechanisms, 6 (86%) were gunshot wounds, and 1 (14%) was an industrial accident. Twelve patients (18%) were old (age ≥65 years; mean age, 76 ± 2 years; 58% male; ISS, 20 ± 2; all blunt trauma), and 54 (82%) were young (age <65 years; mean age, 37 ± 2 years; 61% male; ISS, 32 ± 2; 87% blunt trauma). None of these patients had incurred severe brain injury (ie, Glasgow Coma Scale score ≤8 in the STICU and brain computed tomographic scan abnormalities).

The demographics, risk and incidence of MOF, and outcomes of the old compared with young patients are described in **Table 1**. The mean old age was more than twice that of the young group, but the male gender fraction was similar. The ISS for the old group (20 ± 2; range, 10-38) differed from the ISS for the young patients (32 ± 2; range, 9-75) ($P = .02$). Significant hemorrhage re-

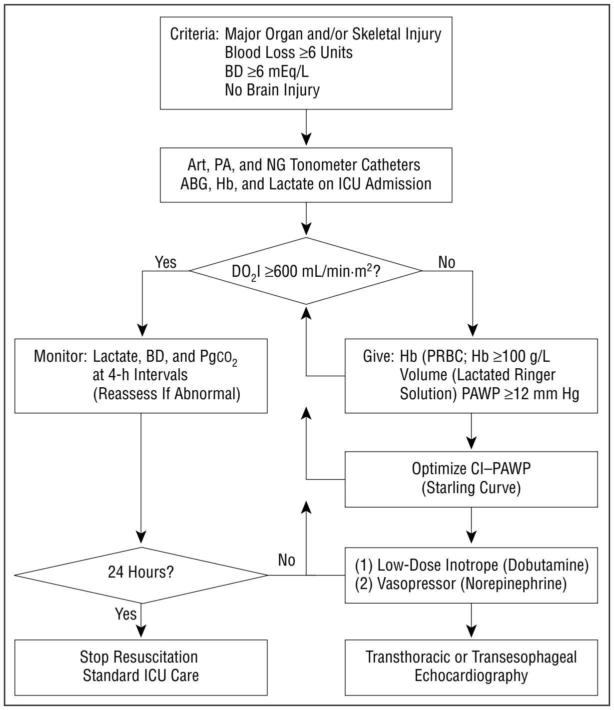

Figure 1. *Summary flowchart diagram of standardized resuscitation protocol for the severe trauma patient. Criteria for presumptive pulmonary artery (PA) catheterization to guide early shock resuscitation are determined by the attending trauma surgeon. The goal of oxygen delivery index (DO_2I) of 600 mL/min·m^2 or greater and the variables that are monitored and controlled to attain and maintain the goal, pulmonary artery wedge pressure (PAWP) and systemic hemoglobin concentration (Hb), are indicated as a set of rules in a logical sequence with measurable thresholds for accurate, timely intervention by the bedside nurse-physician team. Indices of tissue perfusion, base deficit (BD), lactate, and gastric mucosal interstitial PCO_2 ($PgCO_2$) are also monitored throughout the 24-hour resuscitation process. ICU indicates intensive care unit; PRBC, packed red blood cells; Art, arterial; NG, nasogastric; ABG, arterial blood gas analysis; and CI, cardiac index.*

Table 1. Demographics, Risk Factors, Incidence of Multiple Organ Failure, and Outcomes for Shock Resuscitation Patients*

Variable	Old (≥65 y) Patients (n = 12)	Young (<65 y) Patients (n = 54)
Age, y†	76 ± 2	37 ± 2
Gender, % male	58	61
ISS†	20 ± 2	32 ± 2
Required ≥6 U of PRBC in first 24 h	9 (75)	44 (82)
Maximum base deficit in first 12 h	8.9 ± 2.0	7.0 ± 0.7
Maximum lactate in second 12 h	3.4 ± 0.8	4.3 ± 0.4
Multiple organ failure†	6 (50)	10 (19)
ICU length of stay, d	25 ± 9	23 ± 2
Mechanical ventilation, d	24 ± 9	19 ± 3
Survival, 7 d	11 (92)	51 (94)
Survival, 30 d†	5 (42)	48 (89)

**Data are given as mean ± SEM or number (percentage) of patients. ISS indicates Injury Severity Score; PRBC, packed red blood cells; and ICU, intensive care unit.*

†*$P<.05$.*

quiring 6 units or more of PRBC in the first 12 hospital hours occurred in 75% and 82% of old and young patients, respectively, and average maximum BD during the first 12 hours and average maximum lactate during the second 12 hours of resuscitation were nearly equal, indicating similar severity of shock and risk of MOF for both groups. Whereas the incidence of MOF was greater for the old than the young patients (50% vs 19%; $P=.02$), the duration of mechanical ventilation was similar for both groups (old patients: mean, 24 ± 9 days; range, 0-115 days; young patients: 19 ± 3 days; range, 0-70 days) as was ICU length of stay (old patients: 25 ± 9 days; range, 0-115 days; young patients: 23 ± 2 days; range, 0-73 days). Of note, the survival rate at 7 days was the same for old and young patients (92% vs 94%).

Table 2 shows hemodynamic variables at the start of resuscitation and at 4-hour intervals for the old and young groups; **Figure 2** depicts the trends of DO_2I and CI for 36 hours, including the 24-hour resuscitation. At the start of resuscitation, on average, the old patients had a CI of 2.0 ± 0.2 L/min·m^2 and an SVRI of 3344 ± 659 dyne·s/cm^5·m^2, whereas the young patients had a CI of 3.0 ± 0.2 L/min·m^2 ($P=.01$) and an SVRI of 2608 ± 214 dyne·s/cm^5·m^2, with corresponding DO_2Is of 263 ± 26 and 445 ± 30 mL/min·m^2 ($P=.01$). For the old patients, on average, CI increased to 3.3 ± 0.4 L/min·m^2 after 4 hours of resuscitation ($P=.01$, compared with start) and averaged 3.7 ± 0.1 L/min·m^2 during the second 12 hours of resuscitation; DO_2I increased to 433 ± 35 mL/min·m^2 after 8 hours ($P=.04$, compared with start) and averaged 523 ± 17 mL/min·m^2 during the second 12 hours of resuscitation. For the young patients, on average, CI increased to 3.7 ± 0.2 L/min·m^2 after 4 hours of resuscitation ($P=.01$, compared with start) and averaged 4.7 ± 0.1 L/min·m^2 during the second 12 hours of resuscitation; DO_2I increased to 530 ± 29 mL/min·m^2 after 4 hours ($P=.04$, compared with start) and averaged 654 ± 14 mL/min·m^2 during the second 12 hours of resuscitation. During the first 12 hours of resuscitation, DO_2I for the old patients was significantly less than that for the young patients (first 12 hours average for the old patients was 386 ± 23 mL/min·m^2 vs 545 ± 14 mL/min·m^2 for the young patients; $P=.02$), but this difference was not significant when compared throughout 24 hours. The PAWP was not significantly different between the groups and did not change significantly for either group (start PAWP for the old patients, 14 ± 2 mm Hg; start PAWP for the young patients, 12 ± 1 mm Hg; average 24-hour PAWP for the old patients, 16 ± 0.3 mm Hg; average 24-hour PAWP for the young patients, 15 ± 0.2 mm Hg). The SVRI was not significantly different between the groups but decreased significantly for both groups during the first 2 hours of resuscitation (start SVRI for the old patients, 3344 ± 659 dyne·s/cm^5·m^2; start SVRI for the young patients, 2608 ± 214 dyne·s/cm^5·m^2; average 24-hour SVRI for the old patients, 1767 ± 56 dyne·s/cm^5·m^2; average 24-hour SVRI for the young patients, 1517 ± 19 dyne·s/cm^5·m^2).

Table 2 also shows indices of tissue perfusion, ie, BD, lactate, and $PgCO_2$, at the start and at 4-hour intervals throughout resuscitation for the old and young groups; Figure 2 depicts trends for BD and lactate. These variables responded differently for both groups. At the start of resuscitation, neither BD nor lactate was different between the groups (starting BD for the old pa-

Table 2. Hemodynamic Variables and Indices of Tissue Perfusion During Standardized Resuscitation*

Variable	Time, h: 0	4	8	12	16	20	24
Old Patients (Age ≥65 y; n = 12)							
DO_2I, mL/min · m^2	263 ± 26†	395 ± 54†	433 ± 35†‡	465 ± 38†‡	537 ± 24‡	546 ± 36‡	547 ± 34†
CI, L/min · m^2†	2.0 ± 0.2†	3.3 ± 0.4‡	2.8 ± 0.3†‡	3.5 ± 0.5†‡	4.0 ± 0.3‡	3.6 ± 0.3†‡	3.5 ± 0.2†‡
PAWP, mm Hg	14 ± 2	15 ± 2	17 ± 2	16 ± 1	16 ± 2	18 ± 2	16 ± 1
SVRI, dyne · s/cm^5 · m^2	3344 ± 659	1928 ± 345‡	1868 ± 22‡	1417 ± 183‡	1410 ± 149‡	1562 ± 195‡	1588 ± 130‡
Svo_2	60 ± 4	70 ± 7	76 ± 3	74 ± 3	70 ± 5	71 ± 5	70 ± 6
BD, mEq/L†	7.6 ± 2.0	6.5 ± 1.0	7.2 ± 1.2†	5.1 ± 1.1†	3.9 ± 1.0†	3.7 ± 1.5†	3.2 ± 1.1†
Lactate, mmol/L	5.3 ± 1.0	4.7 ± 0.9	4.5 ± 0.9	4.2 ± 1.0	3.6 ± 1.1	2.9 ± 0.5‡	2.0 ± 0.2‡
$Pgco_2$, mm Hg	40 ± 7	40 ± 4	45 ± 2	43 ± 2	46 ± 2	48 ± 3	44 ± 2
Young Patients (Age <65 y; n = 54)							
DO_2I, mL/min · m^2	445 ± 30†	530 ± 29†‡	591 ± 25†‡	613 ± 22†‡	642 ± 32‡	668 ± 31‡	703 ± 29†‡
CI, L/min · m^2†	3.0 ± 0.2†	3.7 ± 0.2‡	4.2 ± 0.2†	4.3 ± 0.1†‡	4.5 ± 0.2‡	4.8 ± 0.2†‡	5.0 ± 0.2‡
PAWP, mm Hg	12 ± 1	15 ± 1	16 ± 1	16 ± 1	15 ± 1	15 ± 1	15 ± 1
SVRI, dyne · s/cm^5 · m^2	2608 ± 214	1708 ± 75‡	1553 ± 87‡	1430 ± 56‡	1400 ± 73‡	1340 ± 63‡	1249 ± 54‡
Svo_2	68 ± 4	71 ± 2	73 ± 2	75 ± 2	77 ± 2	75 ± 2	77 ± 1
BD, mEq/L†	6.5 ± 0.7	4.2 ± 0.7‡	1.6 ± 0.6‡	1.4 ± 0.5‡	1.2 ± 0.5‡	0.8 ± 0.5‡	0.5 ± 0.5‡
Lactate, mmol/L	6.4 ± 0.5	5.2 ± 0.5‡	4.4 ± 0.4‡	4.0 ± 0.4‡	3.5 ± 0.4‡	3.5 ± 0.4‡	3.4 ± 0.5‡
$Pgco_2$, mm Hg	46 ± 4	49 ± 2	51 ± 2	55 ± 3‡	55 ± 3‡	55 ± 3‡	53 ± 2‡

Values are mean ± SEM. DO_2I indicates oxygen delivery index; CI, cardiac index; PAWP, pulmonary artery wedge pressure; SVRI, systemic vascular resistance index; Svo_2, mixed venous oxygen saturation; BD, arterial base deficit; and $Pgco_2$, gastric mucosal interstitial Pco_2.

†*$P<.05$, old compared with young.*

‡*$P<.05$ compared with start of resuscitation.*

tients, 7.6 ± 2.0 mEq/L; starting lactate for the old patients, 5.3 ± 1.0 mmol/L; starting BD for the young patients, 6.5 ± 0.7 mEq/L; starting lactate for the young patients, 6.4 ± 0.5 mmol/L). On average, increased BD persisted for the old patients during the 24-hour resuscitation, did not decrease significantly, and remained greater than 2.0 mEq/L at 24 hours. For the young patients, BD decreased significantly, and BD less than 2 mEq/L was established within 8 hours. The time course of BD differed between the groups ($P=.04$). The time course for lactate was not significantly different between the groups but, on average, decreased significantly for both groups. Average lactate was 2.0 ± 0.2 mmol/L (within <2.5 mmol/L of normal limits) at 24 hours for the old patients, but lactate was 3.4 ± 0.5 mmol/L at 24 hours for the young patients. The $PgCO_2$ was not significantly different between the old and young groups during the 24-hour resuscitation process, but, on average, $PgCO_2$ was greater for the young patients throughout (starting $PgCO_2$ for the old patients, 40 ± 7 mm Hg; starting $PgCO_2$ for the young patients, 46 ± 4 mm Hg; average 24-hour $PgCO_2$ for the old patients, 44 ± 1 mm Hg; average 24-hour $PgCO_2$ for the young patients, 52 ± 1 mm Hg). The $PgCO_2$ increased gradually during the 24-hour resuscitation process for both groups and increased significantly for the young group to 53 ± 2 mm Hg ($P=.01$).

Table 3 describes the therapeutic interventions used during resuscitation and the standardized protocol end points for the interventions. For the old patients, 9 (75%) attained $DO_2I \geq 600$, and 2 (17%) did so within the first 12 hours of resuscitation; 10 (83%) progressed to receive inotrope and 3 (25%) received vasopressor support as part of the 24-hour resuscitation protocol. For the young patients, 45 (83%) attained $DO_2I \geq 600$, and 40 (74%) did so within the first 12 hours of resuscitation; 17 (31%) received inotrope and 10 (19%) received vasopressor support. The average dose rate of dobutamine, the protocol-directed inotrope agent, was 8 ± 1 µg/min · kg (range, 2.5-15 µg/min · kg) and 5 ± 1 µg/min · kg (range, 1-20 µg/min · kg), respectively, for the old and young patients who received it. The average volumes infused during the 24-hour resuscitation process were 16 ± 3 L of crystalloid and 12 ± 3 units of PRBC (volume ratio, 7.4 L of crystalloid per liter of PRBC) for the old patients and 21 ± 2 L of crystalloid and 19 ± 2 units of PRBC (volume ratio, 6.7 ± 1.4 L of crystalloid per liter of PRBC) for the young patients, which were not significantly different between the groups.

COMMENT

Resuscitation methods are controversial, as is the use of pulmonary artery catheters in critically ill patients.[5-7] The concept that maximizing oxygen delivery improves outcome has been difficult to prove and appears to be both patient and time dependent. The trials with negative results have largely enrolled septic medical ICU patients in whom resuscitation was begun after organ dysfunction had developed.[8] Trials involving preemptive optimization of oxygen delivery before major surgery and/or in early traumatic shock resuscitation have shown positive results.[8] Because shock is a consistent predictor of postinjury MOF and because a high-risk cohort for MOF can be accurately identified early after trauma,[1-3] we have developed a standardized protocol for shock resuscitation. The intent of the standardized protocol process is to enable timely, accurate decision making by the bedside clinician team based on essential, current diagnostic data for accurate interventions as required by the individual patient. The standardized protocol process also

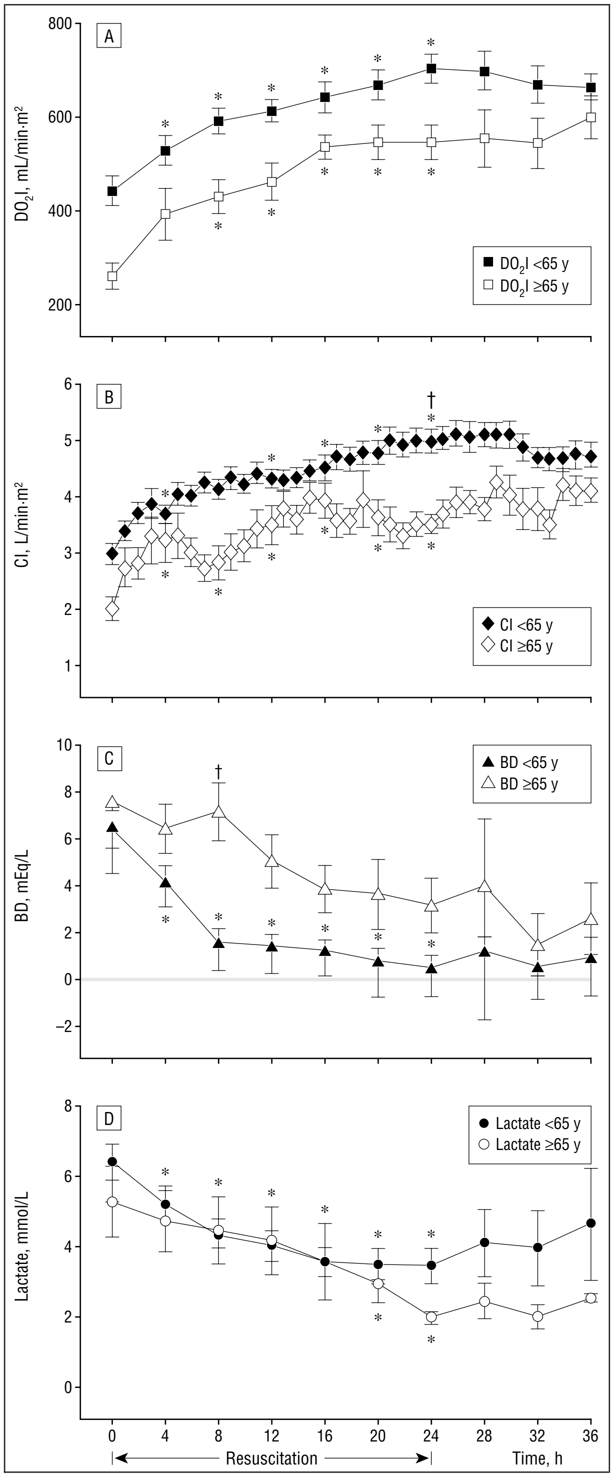

Figure 2. *A, Oxygen delivery index (DO_2I) vs time, showing significant increases after start of resuscitation within 8 hours for old (≥65 years; n=12) and within 4 hours for young (<65 years; n=54) patient groups. On average, the old patients did not attain DO_2I of 600 mL/min·m² or greater within the 24-hour resuscitation process but maintained DO_2I of approximately 550 mL/min·m² from approximately 16 to 24 hours. B, Cardiac index (CI) vs time, showing CI for the old to be significantly less than that for the young patient group at the start and during the 24-hour resuscitation process. C, Base deficit (BD) vs time, showing an insignificant difference at the start of resuscitation between old and young patient groups, significant decrease to less than 2 mEq/L for the young patient group within 8 hours of the start of resuscitation, and a more gradual decrease for the old patient group. D, Lactate concentration vs time, showing a nonsignificant difference at the start of resuscitation between old and young patient groups and significant decrease within 4 hours (although, on average, >3.0 mmol/L for the young patient group after 24 hours and more gradual decrease to <2.5 mmol/L after 24 hours for the old patient group). Asterisk indicates significant at* $P<.05$ *compared with start of resuscitation; dagger,* $P<.05$*, old compared with young patient groups.*

Table 3. Therapeutic Interventions During Resuscitation and Standardized Protocol End Points for Interventions*

	Old Patients (Age ≥65 y; n = 12)	Young Patients (Age <65 y; n = 54)
Intervention		
Crystalloid infusion	12 (100)	54 (100)
24-h Volume of crystalloids, L	16 ± 3	21 ± 2
PRBC transfusion	12 (100)	54 (100)
24-h Volume of PRBC, U	12 ± 3	19 ± 2
Inotrope (dobutamine)	10 (83)†	17 (31)
Dobutamine dose rate, µg/min · kg	8 ± 1	5 ± 1
Vasopressor	3 (25)	10 (19)
Protocol end point		
DO_2I ≥600 mL/min · m²		
In first 12 h	2 (17)	40 (74)
In second 12 h	7 (58)	40 (74)

**Data are given as mean ± SEM or number (percentage) of patients. PRBC indicates packed red blood cells; DO_2I, oxygen delivery index.*

†$P<.05$.

enables prospective data acquisition for review and possible modification of the process in response to specific issues or questions.[9]

It is well known that elderly trauma patients have a much less favorable chance of recovery or survival than younger patients, and it is therefore often assumed that intensive resuscitation efforts are futile. Our data confirm that the rate of survival for elderly severe trauma patients 65 years or older is much less than that for the younger adult trauma cohort but that the rate of 7-day survival is the same, and 30-day survival following our intensive resuscitation is significant (Table 1). Our data show that elderly patients have the ability to respond favorably to a data-driven, goal-directed resuscitation protocol process to an extent that is not significantly different from the younger trauma population. Our data also show that elderly patients have initial prospective indicators of shock (BD, lactate) that are as severe as the younger population at the start of resuscitation, although the ISS indicates apparently less severe tissue injuries (Table 1). These data confirm previously reported findings that elderly trauma patients are at much greater risk of shock and its complications than their younger cohorts and that age is an independent predictor of MOF.[1-4]

At the start of resuscitation, CI appears as the only variable to differ significantly between the old and young groups. This difference reflects a normal elderly cardiac function that is diminished compared with the younger population. Significantly depressed CI contributes to peripheral hypoperfusion and shock, as indicated by significantly abnormal BD (7.6 ± 2.0 mEq/L) and lactate concentrations (5.3 ± 1.0 mmol/L) in the old group at the start of resuscitation. The stress due to trauma and/or hemorrhage plus poor physiologic reserve is extreme in elderly patients and puts these patients at greater risk of shock and its complications.

The DO_2I was significantly less for the old compared with the young patients for the first 12 hours of resuscitation (first 12 hours average DO_2I, 386 ± 23 vs 545 ± 14 mL/min · m^2; $P = .02$). This difference persisted throughout resuscitation during 24 hours (24 hours average DO_2I, 450 ± 18 vs 594 ± 12 mL/min · m^2) and was significantly different during the second 12 hours (second 12-hour average DO_2I, 523 ± 17 vs 654 ± 14 mL/min · m^2; $P = .046$). With no significant difference in Hb or arterial oxygen saturation between the groups, depressed myocardial function in the old compared with the young patients appears as the primary reason for average $DO_2I < 600$, the supranormal performance goal, in the old patient group. This observation is consistent with need for inotropic support in 10 (83%) of the 12 old patients vs 17 (31%) of the 54 young patients, as part of the standardized, data-driven resuscitation protocol process. For the patients who received dobutamine, the protocol-directed inotrope agent, the average dose rate was low to moderate and was not significantly different between groups.

Our experience with elderly patients appears similar to that of Scalea et al,[1] the most recent report addressing the resuscitation of elderly blunt trauma patients with severe diffuse injuries or multiple fractures. In this descriptive report, initial cardiac output less than 3.5 L/min was indicative of vasoconstricted peripheral tissues and impaired oxygen consumption and delivery in the elderly blunt trauma patient. Early aggressive volume loading, and inotrope support if inadequate volume response, was found to improve survival. Survivors had hyperdynamic, vasodilated response (cardiac output, ≈6.6 L/min; systemic vascular resistance, ≈1020 dyne · s/cm^5) and nonsurvivors did not (cardiac output, ≈4.6 L/min; systemic vascular resistance, ≈1470 dyne · s/cm^5). The need for early (emergent) intervention with invasive monitoring and aggressive volume loading therapy within approximately 2 hours after emergency department arrival was found to significantly improve survival compared with approximately 5 hours. Although oxygen consumption and delivery data were not reported, the concept of a regional intracellular oxygen extraction defect in the severe blunt trauma patient, perhaps a predominant effect in the elderly patient, was described, similar to peripheral tissue response to sepsis. Similar to our data, 70% to 90% of elderly blunt trauma patients required inotrope support during early resuscitation. Also similar to our data, survival ranged from 7% to 53%, with improved survival in the emergently monitored, aggressively resuscitated patient group.

More recently, Yu et al[10] studied the effect of maximizing oxygen delivery on mortality and myocardial infarction and found lower mortality in patients that required inotrope support to attain $DO_2I \geq 600$ and no increase in frequency of myocardial infarction due to inotrope support. Yu et al also found that age of 50 years or older predicts inability to generate $DO_2I \geq 600$ with only fluid preload therapy. Consistent with this study, the patients included in our old group did not experience adverse events during our standardized resuscitation process, and 8 (89%) of 9 patients who attained the supranormal goal of $DO_2I \geq 600$ received inotrope support.

The data obtained from elderly blunt trauma patients who were resuscitated using a standardized protocol process indicate that, on average, the old patients respond in a similar manner to young patients, but that the supranormal performance goal of $DO_2I \geq 600$ was not attained. The mean data show a DO_2I plateau of approximately 550 mL/min · m^2 after approximately 16 hours and suggest a maximum DO_2I for the old patient group. Based on the greater sensitivity of the elderly patient to injury and shock, as indicated by early BD and lactate and ISS, it is possible that maximizing oxygen delivery to promptly reestablish peripheral tissue and/or gut perfusion and to prevent secondary insults is at least as beneficial to the elderly patient as to the young patient. Although 7-day survival was not different between the groups, the inability of the old patient group to sustain apparently maximal oxygen delivery equivalent to the young patient group introduces the question of needing to modify the resuscitation end point goal. Further experience and analysis, including a greater number of old patients and comparative analysis of age ranges and outcomes, may show that the supranormal performance goal should be modified to $DO_2I < 600$ for patients older than a certain age, eg, DO_2I of 500 mL/min · m^2 or greater for the blunt trauma patient 65 years or older. We plan to test the response to a submaximal goal as part of ongoing protocol development.

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DISCUSSION

Felix D. Battistella, MD, Sacramento, Calif: Dr McKinley shared with us the findings of a prospective study that implemented a protocol-driven resuscitation in severely injured patients. They compared their results in an older group of patients with those less than 65 years old. First, protocols that codify treatment improve efficiency and in some studies have been shown to reduce morbidity. I agree with their general principles, volume load first with blood and crystalloid, then add inotropes, and as a last resort, add vasopressors. The ideal end point of a resuscitation, however, continues to be as elusive as the holy grail. End points such as oxygen delivery, oxygen consumption, gastric mucosal pH, and others have been advocated. For the past several years, we have used left ventricular stroke work and cardiac power as described by Michael Chang et al as our end point. I am interested in your thoughts regarding your choice of oxygen delivery as a resuscitation end point. Do you have any experience using cardiac power as an end point?

Second, older patients have limited reserves, and as previously described by Tom Scalea et al, older patients with mild to moderate injuries can present with occult shock. The degree of physiologic dysfunction present in this population of patients is not appreciated until invasive monitoring is used. Delays in achieving adequate resuscitation of the older patient who is in shock lead to poor outcomes. Yet, delays in implementing invasive monitoring in treatment of older patients with shock are common, because the hypoperfusion that they are experiencing is clinically occult. What was the length of time between injury and invasive monitoring in your patients? Any treatment delays in the older group might in part explain the higher mortality, despite the lesser degree of injury in this group.

I was surprised that with nearly 1400 ICU admissions, only 12 patients 65 years and older met the criteria for resuscitation based on the standardized protocol. How many patients admitted to the ICU were 65 years and older? Why were they not eligible for enrollment in the study? Since early identification and treatment of older patients in shock is critical to their outcome, what recommendations do you have for expanding your criteria so that this standardized protocol can be implemented in patients who are 65 years or older? Lastly, what were the causes of late deaths in the 6 older patients? Did they die of multiple organ dysfunction as implied in the manuscript? Or, did they die of other causes such as pulmonary embolism, myocardial infarctions, etc? Thanks to many advances, we are living longer, and as the population ages, we will face an epidemic of trauma in the old. This study raises many questions that will need to be addressed in the near future in order to optimize patient outcomes and to avoid overutilization of resources.

Kenneth Waxman, MD, Santa Barbara, Calif: It is apparent from the data that older patients did not reach the oxygen delivery goal in the first 12 hours. We can theorize that this failure led to their late organ failure and death. Was the failure to reach goal oxygen delivery due to physiologic limitations, or is it possible that the therapy was less aggressive in these older patients? Would more aggressive therapy have led to higher deliveries and better outcomes? My second question is whether the 600 $mL/min \cdot m^2$ number for oxygen delivery is the optimal goal for older patients? As the authors know, 600 $mL/min \cdot m^2$ is the average value for survivors. This means that half of the survivors had higher values and half had lower values than 600. Where older patients fell is not clear. Would a better question have been, was flow-limited oxygen consumption exceeded in the older group?

William R. Shiller, MD, Springfield, Ill: These observations confirm and enhance the work of others in trauma and burn patients. Having done similar studies myself, I have some questions. Were the types of injuries as reflected by the AIS scores [Abbreviated Injury Scores] similar in the 2 groups? Specifically, were head-injured patients not studied? It looked to me from your slide that you did not include the head-injured patients. Could you describe some of the complications that you encountered in trying to optimize the hemodynamics of the elderly patient? Although the mixed venous oxygen saturation and the BD trends did not optimize in the elderly group to the extent seen in the young, the 24-hour lactate and the gastric P_{CO_2} values failed to discriminate. Is this a reflection of the weighted use of vasopressors in the younger group or what caused this? I would be interested in your thoughts about that. Lastly, is it possible to rescue patients off the nonsurvivor curves by maximizing their oxygen delivery?

H. Gill Cryer, MD, Los Angeles, Calif: You state that the patients responded effectively to your resuscitation protocol, which is designed to increase oxygen delivery. Did they all respond? Was there a difference in outcome between the patients who responded well and the patients who did not respond very well to the protocol? Second, there have been several prospective randomized trials trying to maximize supernormal values of oxygen delivery. One of those trials actually showed a decrease in survival, in other words, a worse outcome by trying to push the patients. That trial happened to be in a medical ICU, where you would think that most of the patients would probably be elderly and have a lot of comorbid illnesses. Whenever you are doing this and you do not get to the goal that you want, you keep pushing. You keep trying to get there. There is a danger of giving inotropes, for instance, to some of these patients. So, could you tell in your group of patients whether the patients that received high doses of inotropes to try and push that delivery up did worse or better than the patients who did not?

George C. Velmahos, MD, Los Angeles: Your purpose was to identify if therapy was futile among elderly patients with severe trauma. You concluded that it is not. However, the mortality rate was very high among this group, 70%. This means that for 70% of the patients, the therapy was indeed futile. I did not see any comparison between those elderly patients that survived vs those who died. Can you identify any risk factors that predicted the ultimate death of these patients?

James E. Goodnight, MD, Sacramento: We have had 2 papers this morning in which age 65 was the dividing line between shall we say young and old. As we watch the population get better, get healthier, and so forth, we are going to see that what we really should be doing is clustering patients around 55, clustering a group around 65, around 75, 85, and then ultimately 95, and there are going to be dramatic differences between these groups. We will need to look at these as opposed to a single arbitrary dividing line. The authors would agree, we will probably see a dramatic fall off each decade.

There will be also an improvement as time goes on with each cluster.

Dr Moore: Dr Battistella, the optimal end point of resuscitation is controversial. While cardiac performance is important in ensuring adequate peripheral oxygen delivery, the other important component is the hemoglobin level. In the setting of traumatic shock resuscitation, failure to maintain an adequate hemoglobin level is a frequent problem. We, therefore, use DO_2I as an end point because it includes both cardiac performance and hemoglobin level.

In regard to your second question, there were a lot more old patients admitted to the ICU during the study period. Our criteria is age older than 65 years with hemodynamic instability or need for an emergency operation plus evidence of shock (>6 units of blood or elevated BD) or major injury. At our trauma center, elderly patients have abbreviated emergency department evaluations and are triaged to the ICU for close monitoring. Only a small percentage meet the above criteria to be started on the resuscitation protocol. The cause of death in these old patients is late infection (principally pneumonia) and progressive MOF. There are 2 different forms of MOF. Early MOF tends to occur in young patients who have an exuberant proinflammatory response that causes malignant SIRS [systemic inflammatory response syndrome] and early ARDS [adult respiratory distress syndrome]. Old patients do not do this. After 24 hours of resuscitation, they look fairly good. They then get their fractures fixed, but we cannot extubate them. At about day 4 or 5 they develop pneumonia, and given their limited physiologic reserve, this trips them into late MOF.

Dr Waxman questioned whether the old patients did not reach their goal because they received less aggressive treatment. The reason we did this review was to assure ourselves that the old patients could respond to what is perceived by some of the bedside nurses and residents to be overly aggressive. We have provided continuous education concerning the rationale of the protocol, but these data provide the reassurance that the protocol really does work. We are not as aggressive with volume loading in the older patients because they don't respond to it. Our primary goal is to identify high-risk patients as early as possible and then to push oxygen delivery to 600 mL/min · m^2, recognizing that some patients are not going to make it. At 24 hours, we stop the protocol. Normalizing lactate and gastric mucosa carbon dioxide levels or the elimination of flow-dependent oxygen consumption are appealing concepts, but they do not work at the bedside.

Dr Shiller asked about head injuries. In collaboration with our neurosurgeons, we have also developed a similar data-driven intracranial pressure management protocol. To avoid the confusion of competing protocol logic, patients with significant head injuries (Glasgow Coma Scale score $<$8 with abnormal computed tomographic scan) are not placed on the resuscitation protocol unless neurosurgeons have agreed to it. While our neurosurgeons were at first a bit uneasy with the protocol, they agree that head-injured patients should have a hyperdynamic circulation and are now letting more head-injured patients on the protocol.

In response to complications, one of the old patients may have had an acute myocardial infarction; however, it could have been a myocardial contusion. As far as lactate and gastric mucosa carbon dioxide levels being good end points of resuscitation, our experience is that they are not very sensitive. If at 24 hours either of these parameters are high, the patient is not going to do well, but attempts to manipulate these end points are futile.

Dr Cryer, as far as the conflicting results of prospective randomized trials addressing the issue of maximizing oxygen delivery, I believe this is a time- and patient-dependent process. Many of the negative trials have been done in medical ICUs, and at the time of study enrollment, the patients already had sepsis-induced organ dysfunction. It is not surprising that shock resuscitation after end organ injury has already occurred is not going to reverse it. You asked whether our efforts in elderly blunt trauma patients represent futile care. The most dramatic data to refute this concern is that at 7 days 92% of the old patients were alive compared with 95% of the young patients.

Dr Goodnight, our cut point of age older than 65 years was derived from previous prediction models for MOF. You are correct, however; as our database has become more robust, we can demonstrate increasing risk from younger than 45, 45 to 55, 55 to 65, to older than 65 years.

IN OTHER AMA JOURNALS

ARCHIVES OF INTERNAL MEDICINE

Autopsy Consent Practice at US Teaching Hospitals: Results of a National Survey

Glen E. Rosenbaum, MD; Jeffrey Burns, MD; Judy Johnson, JD; Christine Mitchell, RN;
Mary Robinson, MDiv, MA; Robert D. Truog, MD

Background: Autopsy rates continue to fall despite the enduring benefit of the procedure to families and medical science, yet there are few data about the consent process itself.
Objective: To evaluate the current practice of obtaining autopsy consent, by assessing the consent forms currently in use, the knowledge and attitudes of chief residents on the procedure, and the expert opinion of pathologists in those institutions.
Design: Cross-sectional survey.
Settings and Participants: One hundred twenty-seven US teaching hospitals.
Results: Of all autopsy consent forms we surveyed, 84.7% contained 7 of 10 elements recommended by the College of American Pathologists. Only 7.1% of institutions supplied educational materials for the physician, as recommended by the College of American Pathologists. Overall, 50.1% of chief residents reported deficiencies in their knowledge of the autopsy procedure. Correspondingly, greater than 74.5% felt that educational materials would be beneficial for physicians and the family. Finally, 93.3% of chief residents believed that a limited autopsy should be offered to families, while 68 (90%) of 76 pathologists at these institutions believed that limited autopsies are an unsatisfactory alternative to the complete procedure.
Conclusions: Chief residents at US teaching hospitals reported substantial deficiencies in their knowledge about autopsy and desire more training on the consent process. Autopsy consent forms are often lacking information that might help physicians and families in making an educated choice about autopsy. Teaching institutions need to reevaluate the training for the autopsy consent practice. (*2000;160:374-380*)

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