OFFICE OF NAVAL RESEARCH

Contract N00014-80-C-0872

Task No. NR 202-171

FINAL REPORT

Development and Evaluation of a Triage Index for Penetrating Trauma

by

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1 March 1981

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO. AD-A096 342

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) DEVELOPMENT AND EVALUATION OF A TRIAGE INDEX FOR PENETRATING TRAUMA

5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT, Sep 1980 - Mar 1981

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s) WILLIAM J. SACCO; HOWARD R. CHAMPION, WASHINGTON HOSPITAL CENTER

8. CONTRACT OR GRANT NUMBER(s) N00014-80-C-0872

9. PERFORMING ORGANIZATION NAME AND ADDRESS
CYOMETRICS, INC.
25 W. COURTLAND ST.
BEL AIR, MD 21014

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
ONR, Arlington, VA 22217

12. REPORT DATE 1 March 1981

13. NUMBER OF PAGES 20

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report) UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

TRIAGE, TRAUMA SCORE, PENETRATING INJURIES, SURVIVAL PROBABILITIES

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Several new severity scores, the Triage Score, the Triage Index, and Trauma Score, were evaluated for patients with penetrating injuries. The scores, are composed of measures easily obtained by either medical or paramedical personnel using noninvasive techniques and without resorting to instrumentation. The data for the study were obtained from a series of 864 consecutive patients treated at the Washington Hospital Center for penetrating injuries. The data consisted of outcome information (survivor or non-survivor) and coded hospital

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

6 9 10 11 12 26

395661

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20. Abstract (continued)

admission values of seven variables: respiratory expansion, capillary refill, eye opening, best verbal response to stimulus, best motor response to stimulus, respiratory rate, and systolic blood pressure. The Triage Score and Triage Index are functions of the first 5 variables in the list, while the Trauma Score depends on all 7 variables. Probability of survival estimates for the Triage Score, Triage Index, and Trauma Score were obtained using a logistic function method. The predictive 'power' of each of the severity measures was computed for the penetrating injury data. All three measures were extremely powerful predictors of mortality for this data set. Probability of survival estimates were also obtained for the Trauma Score and Triage Score for combined penetrating and blunt injury data.

We believe that the Triage Score or Truama Score could be incorporated into military triage rationales at several echelons of care.

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I. INTRODUCTION

In the article, "Assessment of Injury Seventy-The Triage Index"[1], the authors described a research effort that led to the development of the Triage Score and Triage Index, measures of injury that correlate well with mortality in patients with blunt trauma.

The objective of the current research was to determine the applicability of the Triage Score and Triage Index to patients with penetrating injuries. This objective has been accomplished. Both measures sustained high correlations with mortality for patients with penetrating injuries.

During the period of this research a conference on injury severity scoring systems was organized at Woodstock, Illinois by the Center for Health Research and Development, University of Wisconsin and sponsored by the Center for Health Services Research, U.S. Department of Health and Human Services, and the American Trauma Society. At this conference the Triage Score was subjected to peer review by a group of trauma surgeons. It was recommended that systolic blood pressure and respiratory rate be added to the five variables which compose the Triage Score. Also interval weights were selected for the variables by consensus of the physician participants. The new score is called the Trauma Score[2].

As a result, the authors have also applied the Trauma Score to the penetrating injury data. These results are included in this report.

II. BACKGROUND

Under a Department of Human and Health Services Grant the Triage Score and Triage Index[1] were developed as measures of the severity of injury experienced by patients with blunt trauma.

These measures are easily obtained by either medical or paramedical personnel using noninvasive techniques and without resort to instrumentation. They are based on five simple variables (selected from 16 original variables), namely respiratory expansion (X_1), capillary refill (X_2), eye opening (X_3), best verbal response to stimulus (X_4), and best motor response to stimulus (X_5). Each variable is operationally defined. Numerical values were assigned to the normal state of each variable and to each abnormal state in ascending order of dysfunction. The coded values and operational definitions for these variables are contained in Table 1. The Triage Score (TS) is the arithmetic sum of the coded values assigned to each variable. The Triage Index (TI) is a weighted sum of the coded values. That is, TI=B, where

$$B= B_0+B_1X_1+B_2X_2+B_3X_3+B_4X_4+B_5X_5.$$

The weights $B_0, B_1, \ldots, B_5$ are obtained by fitting patient hospital admission and outcome data to a logistic function of the form $P_s(B)=1/(1+e^{-B})$ (1)

where $P_s(B)$ is the "smoothed" estimate of probability of survival for any value of B.

The data used to obtain the weights were from a series of 1084 blunt trauma patients seen at the Washington Hospital Center, Washington, D.C. over a 2 1/2 year period from September 1976- May 1978. These same data and equation (1) were used to obtain probability of survival estimates for the values of the Trauma Score. In this computation $B=B_0+B_1x(TS)$.

Both the Triage Score and Triage Index were powerful predictors of mortality.

The purpose of the research reported in this paper was to apply both measures to patients with penetrating injuries. It was hoped that the prognostic power would be sustained for this patient set. That this was the case is demonstrated in the Results Section. In fact, both the TS and TI were better predictors of mortality for penetrating injuries than for blunt injuries. The paper also includes results for combined blunt and penetrating injury data.

III. METHODOLOGY

A. Penetrating Injury Study

The data for this study were obtained from a series of 864 consecutive patients treated at the Washington Hospital Center for gunshot or stab wounds during the period September 1976- September 1980. The data consisted of outcome information (survivor or non-survivor) and coded hospital admission values of seven variables: respiratory expansion, capillary refill, eye opening, best verbal response to stimulus, best motor response to stimulus, respiratory rate and systolic blood pressure.

The Triage Score and Triage Index are functions of the first five variables in this list, while the Trauma Score (defined in Table 2) is a function of all seven variables. For each coded value of the seven variables and the Glascow Coma Scale* the ratio, number of survivors/total number of patients, was computed. These ratios were used as probability of survival estimates for each coded value. Probability of survival estimates for the Triage Score, Triage Index, and Trauma Score were obtained using the logistic function method discussed in the Background Section.

The predictive power (with respect to mortality) of the seven variables; the Glascow Coma Scale; and the Triage Score, Triage Index, and Trauma Score was assessed by the PER method. PER, which has become a cornerstone in our methodology, is an acronym. "P" in the acronym is the "a priori" probability of survival (the survival rate) for all patients in the population being analyzed. The information gain, "E", for an index is the average improvement (over a priori probability) in the estimation of the probability of survival based on the index. More explicitly $E=\sum_{X}|P-P_s(X)|\,f(X)$, where $P_s(X)$ is the probability of survival given X (the value of a variable or an index), and f(X) is the relative occurrence of X in the population. If an index were perfect, it would have an information gain of 2P(1-P). Indeed a perfect index would be either correctly

* The Glascow Coma Scale[3] is composed of three neurological parameters (see Table 2). It has been incorporated into the Trauma Score.

making predictions of <u>certain</u> survival ($P_S=1$) or correctly making predictions of <u>certain</u> death ($P_S=0$). Certain survival would be predicted P fraction of the time, in which case the information gain is (1-P). On the other hand, predictions of certain death occur (1-P) fraction of the time, in which case, the information gain is P. Therefore the average information gain for a perfect predictor is: $P(1-P) + (1-P)P$ or $2P(1-P)$. For example, if a variable or index were perfect in a treatment facility where the survival rate was 90% ($P=0.90$), then $2P(1-P)=0.18$. If a variable were perfect in a facility with a survival rate of 50% ($P=0.5$), then $2P(1-P)=0.50$. Hence numerical values of E are not directly comparable, but can be normalized with respect to a perfect index for the same level of P. This figure is "R" in the acronym. It represents the relative information gain, and is defined by the following ratio: $R= E/2P(1-P)$. R, which takes on values from 0 to 1, is a measure of the predictive power of a variable or an index. High R values imply that a variable or an index has high predictive power relative to a perfect predictor.

The performance of the Triage Score, Triage Index and Trauma Score were also assessed using misclassification rates and the difference [$\bar{P}_S$ (survivors)- $\bar{P}_S$ (non-survivors)] where $\bar{P}_S$ (survivors) is the average probability of survival taken over the set of survivors and $\bar{P}_S$ (non-survivors) is the average probability of survival taken over the set of non-survivors.

B. Combined Penetrating and Blunt Injury Study

The two data sets (blunt and penetrating) were combined and used to obtain probability of survival estimates for the Triage Score and the Trauma Score using the logistic function method.

IV. RESULTS

A. Penetrating Injury

Probability of survival estimates and relative frequencies of occurrence for each coded value of the seven hospital admission variables, the Glascow Coma Scale, the Triage Score, and the Trauma Score are contained in Tables 3 to 5. Data items were missing on some patients accounting for different totals in the various tables.

PER values for each variable and score, for the Glascow Coma Scale, and for the Triage Index are contained in Table 6. Table 7 contains average probabilities of survival (for the set of survivors and for the set of non-survivors) for the Triage Score, Triage Index, and the Trauma Score.

The weights for the Triage Index were computed to be $B_0=8.2055$, $B_1=-0.8920$, $B_2=-1.7417$, $B_3=0.0845$, $B_4=-1.1293$, $B_5=-0.0329$. Equation (1) can be used to compute probability of survival values for the Triage Index where $X_1,\ldots X_5$ are, respectively, coded values for the respiratory expansion, capillary refill, eye opening, best verbal response, and best motor response.

B. Combined Penetrating and Blunt Injuries

Probability of survival estimates for this Triage Score and Trauma Score are contained in Tables 8 and 9 for the combined data sets.

V. DISCUSSION

The Triage Score, Trauma Score, and Triage Index have all been demonstrated to be powerful predictors of morality for patients with penetrating injuries as measured by the relative information gains (R values:Table 6) and differences between average probability of survival for the set of survivors and for the set of non-survivors (Table 7).

The R values of 0.86, 0.90, and 0.90 actually exceed the values of 0.72, 0.73, and 0.76 obtained previously for blunt trauma patients. Hence the three severity measures were better predictors of mortality for penetrating injuries than for blunt injuries on our data sets.

These measures address themselves to early moments in the sequence from injury to final outcome, namely, hospital admission assessment of injury severity and judgements in the matching of patients with available therapeutic resources. The results show that the measures have correlated well with mortality in several series of blunt and of penetrating trauma patients. A pertinent example of the utility of the measures are provided by an investigation being conducted at the Washington Hospital Center now. The investigation is concerned with the deployment of the appropriate therapeutic response in stratified treatment systems.

In this example, low intensity and high intensity receiving areas are involved. The low intensity area is the hospital's ED, which is a typical inner city facility constituting a point of patient-controlled access to a full range of emergency and ambulatory medical services. The ED is staffed in a conventional manner, with a full time director, staff attending physicians, resident house staff, and ED nurses and technicians. The high intensity receiving area, termed Medical and Shock Trauma Acute Resuscitation Unit ("MedSTAR") is a provider controlled critical care facility dedicated solely to those emergency patients whose survival is imperiled by their injury.

MedSTAR provides the capability for resuscitative efforts up to and including angiography and open heart surgery within 70 feet of its helipad and is complimented by the immediate adjacency of full radiological support including computed tomography, the Medical and Surgical ICV, and the Burn Unit, all in the same Critical Care Tower. Triage of the injured to MedSTAR versus the ED is obviously a matter of considerable importance. Mistriage of critical patients to the ED may raise the mortality rate. Mistriage of noncritical patients to MedSTAR is costly, and wastes the availability of this specialized resuscitative response. Accordingly, a triage algorithm has been developed which combines historical elements with information derived from the Triage Score in order to reduce the mistriage rate.

Both the Triage Score and Trauma Score are based on simple, concise, well-defined instructions requiring no invasive manuevers. Both are arithmetic sums of 5 coded values. Because the Triage Index is more difficult to compute and provides little improvement in mortality prediction over the scores, we would recommend not considering it further at this time.

A number of civilian medical systems are considering the implementation of the Triage Score and Trauma Score into data collection tools to be used by physicians, nurses, and paramedics in the assessment of a patient at the score of injury, enroute to the hospital, and at the time of hospital admission.

We believe that the scores could be valuable tools in military triage especially if the prognostic "power" prevails for military casualties.

For example, if the goal of triage were to maximize the expected number of survivors, a simplified two-step process of triage may be described as follows:

Step 1: The triager sorts the casualties into several categories including A. those who will survive with little or no medical assistance, B. those who cannot be saved even with the best possible medical care, and C. those who will survive only if they receive substantial medical care.

Step 2: Determine the order of treatment for patients in Category C. In the proposed rationale the casualties in Category C are ordered using the probability of survival, P_S, based on the Triage Score or Trauma Score or based on clinical acumen supported by a score.

A rationale could also include updating estimates of survival probabilities for casualties in a queue waiting for definitive treatment.

The above rationale is intended to be suggestive. A definitive and more realistic procedure may be dependent upon the specific objectives of the triage procedure and on other considerations, pertinent factors, and rationales employed by experienced triagers.

However, it appears that either the Triage Score or Trauma Score could play an important role in most triage rationales.

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3. Teasdale, G., Jennett, B.: Assessment of coma and impaired consciousness. A practical scale. Lancet 2: 81-84, 1974.

TABLE 1

TRIAGE SCORE
VARIABLE DEFINITIONS, METHODS OF ASSESSMENT, AND CODES

VARIABLE	DEFINITION	CODES	
Respiratory Expansion:	Normal	0	A.___
Shallow- markedly decreased chest movement or air exchange	Shallow	2	
Retractive- use of accessory muscles or intercostal retraction	Retractive	2	
	None	3	
Capillary Refill:	Immediate (less than 2 sec)	0	B.___
Immediate- forehead or lip mucosa color refill in 2 seconds	Delayed (more than 2 sec)	2	
Delayed- more than 2 seconds capillary refill			
Eye Opening:	Spontaneous	0	C.___
Spoken or shouted verbal commands or standard pain stimulus	To voice	1	
	To pain	2	
	None	3	
Verbal Response:	Oriented	0	D.___
Conversational ability, e.g., sentences, words only, sounds only	Confused	1	
	Innapropriate words	2	
	Incomprehensible sounds	3	
	None	4	
Motor Response:	Obeys Commands	0	E.___
Spoken or shouted verbal commands or standard pain stimulus	Withdrawal	1	
	Flexion	2	
	Extension	3	
	None	4	

Triage Score ______
(Total A+B+C+D+E)

TABLE 2

TRAUMA SCORE
VARIABLE DEFINITIONS, METHODS OF ASSESSMENT, AND CODES

	Rate	Codes	Score
A. Respiratory Rate	10-24	4	
Number of respirations in 15 seconds;	25-35	3	
multiply by four	> 35	2	
	< 10	1	
	0	0	A.___
B. Respiratory Effort			
Shallow- Markedly decreased chest movement or air exchange	Normal	1	
Retractive- Use of accessory muscles or intercostal retraction	Shallow or Retractive	0	B.___
C. Systolic Blood Pressure	> 90	4	
Systolic cuff pressure- either arm	70-90	3	
auscultate or palpate	50-69	2	
No carotid pulse	< 50	1	
	0	0	C.___
D. Capillary Refill			
Normal- Forehead or lip mucosa color refill in 2 seconds	Normal	2	
Delayed- More than 2 seconds capillary refill	Delayed	1	
None- No capillary refill	None	0	D.___

E. Glasgow Coma Scale

	Points
1. Eye Opening	
Spontaneous	___4
To Voice	___3
To Pain	___2
None	___1
2. Verbal Response	
Oriented	___5
Confused	___4
Inappropriate Words	___3
Incomprehensible Sounds	___2
None	___1
3. Motor Response	
Obeys Commands	___6
Purposeful Movements (pain)	___5
Withdraw (pain)	___4
Flexion (pain)	___3
Extension (pain)	___2
None	___1

Total GCS Points	Score	
14-15	5	
11-13	4	
8-10	3	
5- 7	2	
3- 4	1	E.___

Total GCS Point (1+2+3) ________

TRAUMA SCORE____
(Total Points A+B+C+D+E)

TABLE 3

PROBABILITY OF SURVIVAL ESTIMATES FOR EACH STATE OF EACH ADMISSION VARIABLE

VARIABLE	STATE		NUMBER OF SURVIVORS	NUMBER OF DEATHS	FRACTION OF TOTAL PATIENTS	PROBABILITY OF SURVIVAL, P_s
Respiratory expansion (648 patients)	Normal		472	8	0.74	0.98
	Shallow/Retractive		95	16	0.17	0.86
	None		5	52	0.09	0.088
		TOTAL	572	76		
Capillary refill (616 patients)	Immediate		459	7	0.76	0.98
	Delayed		82	68	0.24	0.55
		TOTAL	541	75		
Eye opening (681 patients)	Spontaneous		559	14	0.84	0.98
	Voice		26	2	0.04	0.93
	Pain		4	1	0.01	0.80
	None		12	63	0.11	0.16
		TOTAL	601	80		
Best verbal response (692 patients)	Oriented		564	8	0.83	0.99
	Confused		20	2	0.03	0.91
	Inappropriate words		3	2	0.01	0.60
	Incomprehensible sounds		8	2	0.01	0.80
	None		17	66	0.12	0.20
		TOTAL	612	80		

TABLE 3 (CONTINUED)

VARIABLE	STATE		NUMBER OF SURVIVORS	NUMBER OF DEATHS	FRACTION OF TOTAL PATIENTS	PROBABILITY OF SURVIVAL, P_s
Best Motor response (691 patients)	Obey		585	11	0.86	0.98
	Withdraw		14	7	0.03	0.67
	Flexion		0	4	0.01	0.00
	Extension		1	0	0.00	1.00
	None		12	57	0.10	0.17
		TOTAL	612	79		
Glascow Coma Scale (669 Patients)	[3,4]		9	60	0.10	0.13
	[5,6,7]		4	2	0.01	0.67
	[8,9,10]		9	6	0.02	0.60
	[11,12,13]		19	2	0.03	0.90
	[14,15]		549	9	0.83	0.98
		TOTAL	590	79		
Systolic blood pressure (864 patients)	0-10		8	52	0.07	0.13
	11-49		3	2	0.01	0.60
	50-69		15	9	0.03	0.63
	70-90		52	6	0.07	0.90
	> 90		698	19	0.83	0.97
		TOTAL	776	88		
Respiratory rate (779 patients)	0		4	55	0.08	0.068
	1-9		1	4	0.01	0.20
	10-24		567	10	0.74	0.98
	25-35		102	3	0.13	0.97
	> 35		30	3	0.04	0.91
		TOTAL	704	75		

TABLE 4

PROBABILITY OF SURVIVAL ESTIMATES FOR EACH VALUE OF THE TRIAGE SCORE (COMPUTED FROM THE LOGISTIC FUNCTION FOR THE PENETRATING INJURY DATA SET)

TRIAGE SCORE	NUMBER OF SURVIVORS	NUMBER OF DEATHS	FRACTION OF TOTAL PATIENTS	PROBABILITY OF SURVIVAL, P_s
0	376	3	0.643	0.99
1	11	0	0.019	0.99
2	65	0	0.110	0.98
3	11	0	0.019	0.97
4	25	4	0.049	0.96
5	7	0	0.019	0.94
6	3	2	0.008	0.90
7	5	0	0.008	0.85
8	1	0	0.002	0.79
9	0	1	0.002	0.70
10	4	4	0.014	0.60
11	2	1	0.005	0.48
12	0	0	0.000	0.37
13	0	7	0.019	0.27
14	2	2	0.007	0.19
15	5	5	0.017	0.13
16	0	43	0.073	0.037
TOTAL	517	72		

589 PATIENTS

TABLE 5

PROBABILITY OF SURVIVAL ESTIMATES FOR EACH VALUE OF THE TRAUMA SCORE (COMPUTED FROM THE LOGISTIC FUNCTION FOR THE PENETRATING INJURY DATA SET)

TRAUMA SCORE	NUMBER OF SURVIVORS	NUMBER OF DEATHS	FRACTION OF TOTAL PATIENTS	PROBABILITY OF SURVIVAL, P_s
16	289	2	0.546	1.00
15	94	1	0.178	1.00
14	37	1	0.071	1.00
13	24	0	0.045	0.99
12	8	1	0.017	0.97
11	5	3	0.015	0.91
10	6	2	0.015	0.80
9	3	0	0.006	0.58
8	2	2	0.008	0.33
7	0	2	0.004	0.15
6	0	6	0.011	0.06
5	0	2	0.004	0.02
4	0	3	0.006	0.01
3	0	2	0.004	0.00
2	1	37	0.071	0.00
1	0	0	0.000	0.00
TOTAL	469	64		

533 PATIENTS

TABLE 6

PER VALUES FOR EACH VARIABLE, THE GLASCOW COMA SCALE, AND THE TRIAGE SCORE, TRAUMA SCORE, AND TRIAGE INDEX

VARIABLE	P	E	R
Respiratory expansion	0.89	0.15	0.72
Capillary refill	0.88	0.16	0.76
Eye opening	0.88	0.16	0.77
Best verbal response	0.88	0.17	0.83
Best motor response	0.89	0.17	0.82
Glascow Coma Scale	0.88	0.17	0.82
Systolic blood pressure	0.90	0.13	0.68
Respiratory rate	0.90	0.14	0.78
Triage Score	0.88	0.18	0.86
Trauma Score	0.88	0.19	0.90
Triage Index	0.88	0.19	0.90

TABLE 7

AVERAGE PROBABILITIES OF SURVIVAL, $\bar{P}_s$, (FOR THE SET OF SURVIVORS AND FOR THE SET OF DEATHS) FOR THE TRIAGE SCORE, TRIAGE INDEX, AND THE TRAUMA SCORE

MEASURE	$\bar{P}_s$	
	SURVIVORS	NON-SURVIVORS
Triage Score	0.97	0.27
Triage Index	0.97	0.25
Trauma Score	0.99	0.17

TABLE 8

PROBABILITY OF SURVIVAL ESTIMATES FOR EACH VALUE OF THE TRIAGE SCORE (COMPUTED FROM THE LOGISTIC FUNCTION FOR THE COMBINED BLUNT AND PENETRATING INJURY SETS

TRIAGE SCORE	FRACTION OF TOTAL PATIENTS	PROBABILITY OF SURVIVAL, P_s
0	0.68	0.99
1	0.037	0.98
2	0.092	0.97
3	0.019	0.96
4	0.032	0.94
5	0.012	0.92
6	0.0091	0.88
7	0.010	0.83
8	0.0055	0.76
9	0.0036	0.68
10	0.010	0.59
11	0.0061	0.48
12	0.0024	0.38
13	0.013	0.29
14	0.0055	0.21
15	0.012	0.15
16	0.047	0.11

1633 Patients (Blunt and Penetrating)
155 Deaths

TABLE 9

PROBABILITY OF SURVIVAL ESTIMATES FOR EACH VALUE OF THE TRAUMA SCORE (COMPUTED FROM THE LOGISTIC FUNCTION FOR THE COMBINED BLUNT AND PENETRATING INJURY SETS

TRAUMA SCORE	FRACTION OF TOTAL PATIENTS	PROBABILITY OF SURVIVAL, P_s
16	0.64	0.99
15	0.16	0.98
14	0.064	0.96
13	0.037	0.93
12	0.023	0.87
11	0.013	0.76
10	0.015	0.60
9	0.0053	0.42
8	0.0040	0.26
7	0.0033	0.15
6	0.0066	0.08
5	0.0013	0.04
4	0.0033	0.02
3	0.0013	0.01
2	0.044	0.00
1	0	0.00

1509 Patients (Blunt and Penetrating)
139 Deaths

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