FAST Ultrasound Examination as a Predictor of Outcomes After Resuscitative Thoracotomy

A Prospective Evaluation

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Objective: The objective of this study was to examine the ability of Focused Assessment Using Sonography for Trauma (FAST) to discriminate between survivors and nonsurvivors undergoing resuscitative thoracotomy (RT).

Background: RT is a high-risk, low-salvage procedure performed in arresting trauma patients with poorly defined indications.

Methods: Patients undergoing RT from 10/2010 to 05/2014 were prospectively enrolled. A FAST examination including parasternal/subxiphoid cardiac views was performed before or concurrent with RT. The result was captured as adequate or inadequate with presence or absence of pericardial fluid and/or cardiac motion. A sensitivity analysis utilizing the primary outcome measure of survival to discharge or organ donation was performed.

Results: Overall, 187 patients arrived in traumatic arrest and underwent FAST. Median age 31 (1–84), 84.5% male, 51.3% penetrating. Loss of vital signs occurred at the scene in 48.1%, en-route in 23.5%, and in the ED in 28.3%. Emergent left thoracotomy was performed in 77.5% and clamshell thoracotomy in 22.5%. Sustained cardiac activity was regained in 48.1%. However, overall survival was only 3.2%. An additional 1.6% progressed to organ donation. FAST was inadequate in 3.7%, 28.9% demonstrated cardiac motion and 8.6% pericardial fluid. Cardiac motion on FAST was 100% sensitive and 73.7% specific for the identification of survivors and organ donors.

Conclusions: With a high degree of sensitivity for the detection of potential survivors after traumatic arrest, FAST represents an effective method of separating those that do not warrant the risk and resource burden of RT from those who may survive. The likelihood of survival if pericardial fluid and cardiac motion were both absent was zero.

Keywords: arrest, injury, resuscitation, trauma, ultrasound

For patients presenting in traumatic cardiac arrest, a resuscitative thoracotomy (RT)[1] performed in the Emergency Department is often utilized as a final salvage maneuver. The quantitative yield on this procedure, however, is exceedingly low. Although proponents would argue that there is little to lose as not intervening would invariably end in death, there is a collateral impact on society because of resource utilization and the potential risk of harm to the trauma care providers.[2–4] Despite the controversy, RT does yield survivors.[5–15] In one of the largest series to date, Rhee reviewed 4620 cases over a 25-year period, documenting a survival rate of 7.4% with normal neurologic function in 92.4% of survivors.[16] Long-term survival with normal cognition and return to normal activity without evidence of post-traumatic stress disorder has also been demonstrated.[17] In addition to survival, organ donation is an important, tangible outcome after this procedure,[13] with a direct benefit to society.

The ability of both clinical criteria[18–22] and laboratory findings[23] to discriminate between survivors and nonsurvivors has been examined. As summarized in a recent Western Trauma Association critical decisions review,[24] there is a paucity of high quality data upon which recommendations can be based. As a direct result, despite comprehensive consensus statements by groups such as the NAEMSP-ACSCOT on withholding and terminating resuscitation after traumatic arrest[25,26] and guidelines on the initiation of RT by the American College of Surgeons,[27] universally accepted criteria for who should and should not undergo this emergent procedure do not exist at this time.

The Focused Assessment Using Sonography for Trauma (FAST) examination, performed at the bedside by a nonradiologist clinician, has become a standard of care diagnostic procedure in the management of injured patients. In penetrating cardiac trauma, for example, it has been demonstrated to have near perfect sensitivity and a very high specificity[28] for hemopericardium and is the immediate test of choice for patients at risk for cardiac injury in the resuscitation area. It is often the sole test that is utilized to decide on the operative versus nonoperative management of patients with potential cardiac injury. It can be rapidly performed within seconds of arrival and repeated frequently, with little patient preparation or movement required and no radiation burden. Importantly, it can be performed concurrently with any life saving interventions. Outside of the trauma population, but highly relevant to the current study, point of care ultrasound has also been demonstrated to be highly effective for visualizing cardiac motion, the absence of which is strongly correlated with nonsurvivability in the nontraumatic arrest patient.[29,30]

The purpose of this study was to examine the ability of the bedside FAST examination to discriminate between survivors and nonsurvivors after RT. As organ donation is an important clinical outcome after traumatic arrest, the ability of FAST to identify organ donors was also assessed. Our hypothesis was that for patients presenting in traumatic cardiac arrest, FAST would be able to separate survivors and organ donors from those in whom a RT is futile.

METHODS

After institutional review board approval, all patients undergoing an RT in the Emergency Department, at the Los Angeles County + University of Southern California (LAC+USC) Medical Center, between October 2010 and May 2014 were enrolled in a prospective observational trial. The RT was initiated on patients in cardiac arrest

at the discretion of the attending trauma surgeon or in their absence the attending emergency medicine physician or the most senior member of the trauma team present. In general, all penetrating trauma patients with absent vital signs and blunt trauma patients with a loss of vital signs en route or in the resuscitation bay underwent RT.

Only thoracotomies performed in the Emergency Department, immediately upon arrival, were analyzed in this study. Patients undergoing an emergent or urgent thoracotomy in the Operating Room were excluded. Injury and patient demographics, operative details, injury burden and clinical outcomes were prospectively documented. The primary outcome was survival to discharge or organ donation. Other outcomes of interest included the return of organized cardiac activity with spontaneous circulation after RT which was defined as a spontaneously beating heart without the need for external cardiac manipulation or the infusion or intermittent dosing of inotropic medications.

The FAST was performed justbefore, or concurrent with the thoracotomy. FAST examinations during the study period were performed by PGY 2–4 emergency medicine residents under direct faculty supervision. As part of their standard residency training and before participation in the study, all residents completed a 2 day, 16 hour ultrasound course consisting of didactics and hands on training, in addition to a minimum of 2 weeks of proctored training in point of care ultrasound, following national emergency medicine guidelines.[31] All residents were trained in the identification of pericardial effusion, cardiac activity and cardiac standstill. Ultrasound examinations were performed on an S-FAST or M-Turbo machine (SonoSite, Bothell, WA) with a 5–1 MHz phased array transducer. Both a parasternal and/or subxiphoid views were obtained. The ultrasound findings were prospectively documented as adequate or inadequate. If adequate, the presence or absence of pericardial fluid and cardiac motion were captured. Cardiac motion was defined as organized, nonfibrillating contractions of the heart. Continuous variables were dichotomized using clinically relevant cut points: systolic blood pressure on admission (<90 mm Hg vs ≥ 90 mm Hg), Injury Severity Score (≤ 15, 16–24, or ≥ 25), and heart rate on admission (≥ 60 or ≤ 120 bpm vs >120 or <60 bpm).

Categorical variables were compared using the Fisher exact test or Pearson χ^2 test, as appropriate. Continuous variables were compared using Mann-Whitney U test. Values are reported as median and interquartile range (IQR) for continuous variables and as percentages for categorical variables. All analysis was performed using SPSS Windows, version 12.0 (SPSS Inc., Chicago, IL). The primary objective of this study was to evaluate the ability of the FAST examination to discriminate between survivors and nonsurvivors in patients who present with traumatic arrest. As organ donation after traumatic arrest is a clinically important positive outcome, survival to organ donation was also analyzed along with overall survival. A sensitivity analysis was performed using the primary outcome (alive or organ donor versus dead) as the gold standard in the assessment of the findings of the FAST results (positive cardiac motion or pericardial fluid versus no motion and no fluid). Secondary outcomes included Length of Stay (LOS) and ICU LOS.

RESULTS

There were 223 cases that underwent an RT between October 2010 and May 2014 at the LAC+USC Medical Center after sustaining a traumatic arrest (Fig. 1). Of the entire study population 187 (83.9%) had a FAST performed forming our study cohort. In the patient cohort that was excluded, there were no survivors or organ donors. The median age was 31 years (range1–84) with males comprising 84.5% of the cases (Table 1). 51.3% of the patients sustained penetrating trauma, with the most common mechanism being a gunshot wound (42.2%) followed by pedestrian struck by auto (22.5%), motor vehicle collision (17.1%) and stab wound (9.1%). This was a severely injured cohort of patients with a median ISS of 34 (IQR 19). The total injury burden was extensive (Table 2) with 46.5% having an associated head injury, 12.8% a pelvic fracture, 29.9% extremity injury, 32.6% a vascular injury and 38% an abdominal injury. Although 22.5% of the patients undergoing RT in the emergency department had a cardiac injury, none of these patients survived. During the study time frame, an additional 21 patients sustained a cardiac injury and survived to discharge. All were penetrating thoracic injuries with a pericardial effusion on FAST and all were emergently brought to the operating room for a planned sternotomy and were ,therefore, excluded from the study. Of this group, 7(33.3%) were profoundly unstable and arrested on entry into the operating room requiring emergent left thoracotomy for the repair. Although these cases were excluded from the analysis, the decision to move to the operating room in all cases was preceded by a FAST examination that was positive for pericardial fluid.

Vital signs were lost at the scene in 48.1%, en-route in 23.5% and in the ED in 28.3%. The majority (85.6%) arrived by ground EMS transport, 11.8% by air and 2.7% by private vehicle. The median duration of transport time was 33 minutes (IQR 15). Field endotracheal intubation was performed in 48.7% of patients. Almost one quarter of our study population (22.5%) underwent bilateral or clamshell thoracotomy with the remainder receiving a standard Left anterolateral thoracotomy. Of all patients that underwent RT, 48.1% regained sustained cardiac motion, however, ultimately only 6 (3.2%) survived and 3 (1.6%) additional patients became organ donors. For survivors, the median ICU LOS was 11 (14) days with an overall hospital LOS
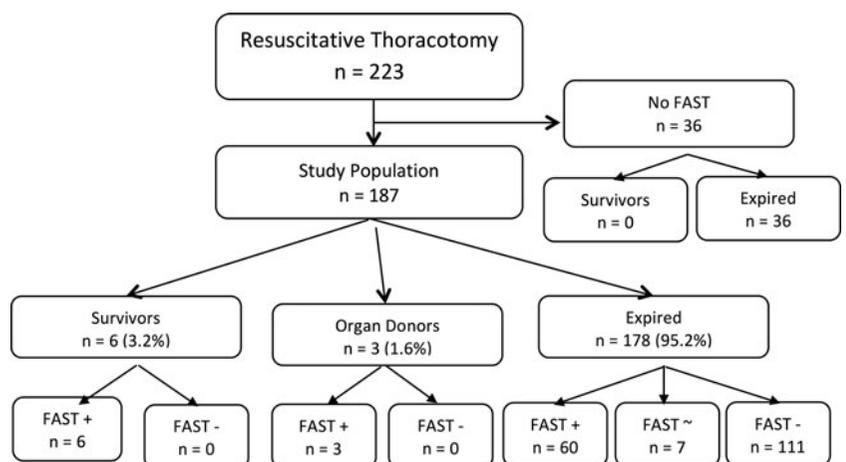

FIGURE 1. Patient flow chart. FAST indicates Focused Assessment with Sonography for Trauma; FAST+, positive for cardiac motion or fluid; FAST−, negative for cardiac motion or fluid; FAST~, inadequate exam.

TABLE 1. Clinical Demographics, Vital Signs, Operative Procedures, and Method of Transportation

	Total (n = 187)	Survivors/ donors (n = 9)	Deaths (n = 178)	P
Demographics				
Age	31 (21)	38 (31)	31 (21)	0.627
Male	158 (84.5%)	8 (88.9%)	150 (84.3%)	1.000
Penetrating	96 (51.3%)	5 (55.6%)	91 (51.1%)	1.000
ISS	34 (19)	25 (28)	34 (20)	0.047
ED Vitals				
SBP<90	145 (77.5%)	4 (44.4%)	141 (79.2%)	0.028
HR>120 OR HR<60	164 (88.2%)	7 (77.8%)	157 (88.7%)	0.288
GCS≤8	168 (90.3%)	8 (88.9%)	160 (90.4%)	1.000
Field intubation	91 (48.7%)	4 (44.4%)	87 (48.9%)	1.000
Cardiac electrical activity	56 (29.9%)	6 (66.7%)	50 (28.1%)	0.022
Vital signs lost				
Scene	90 (48.1%)	2 (22.2%)	88 (49.4%)	0.154
En-route	44 (23.5%)	2 (22.2%)	42 (23.6%)	0.154
ED	53 (28.3%)	5 (55.6%)	48 (27%)	0.154
Operative procedures				
Left thoracotomy	145 (77.5%)	9 (100%)	136 (76.4%)	0.212
Bilateral/clamshell thoracotomy	42 (22.5%)	0	42 (23.6%)	0.212
Exploratory laparotomy	67 (35.8%)	5 (55.6%)	62 (34.8%)	0.286
Transport				
Ground transport	160 (85.6%)	8 (88.9%)	152 (85.4%)	0.202
Air transport	22 (11.8%)	0	22 (12.4%)	0.202
Private vehicle	5 (2.7%)	1 (11.1%)	4 (2.2%)	0.202

The continuous variables are presented as median (interquartile range).
ISS indicates injury severity score; ED, emergency department; SBP, systolic blood pressure; HR, heart rate.

TABLE 2. Injury Distribution

	Total (n = 187)	Survivors/ donors (n = 9)	Deaths (n = 178)	P
Head injury	87 (46.5%)	5 (55.6%)	82 (46.1%)	0.736
Spine injury	8 (4.3%)	2 (22.2%)	6 (3.4%)	0.050
Pelvic injury	24 (12.8%)	2 (22.2%)	22 (12.4%)	0.325
Extremity injury	56 (29.9%)	2 (22.2%)	54 (30.3%)	0.727
Thoracic injury	102 (54.5%)	4 (44.4%)	98 (55.1%)	0.734
Cardiac injury	42 (22.5%)	0	42 (23.6%)	0.212
Lung injury	66 (35.3%)	3 (33.3%)	63 (35.4%)	1.000
Abdominal injury	71 (38%)	5 (55.6%)	66 (37.1%)	0.304
Solid organ injury	53 (28.3%)	2 (22.2%)	51 (28.7%)	1.000
Hollow viscus injury	25 (13.4%)	2 (22.2%)	23 (12.9%)	0.344
Diaphragmatic injury	21 (11.2%)	1 (11.1%)	20 (11.2%)	1.000
Vascular injury	61 (32.6%)	4 (44.4%)	57 (32%)	0.476
Head and neck vascular injury	5 (2.7%)	0	5 (2.8%)	1.000
Thoracic vascular injury	33 (17.6%)	3 (33.3%)	30 (16.9%)	0.198
Abdominal vascular injury	26 (13.9%)	2 (22.2%)	24 (13.5%)	0.363
Extremity vascular injury	5 (2.7%)	0	5 (2.8%)	1.000

of 14 (17) days. Two of the six survivors were discharged home, neurologically intact. Two patients with spinal cord injuries (1 paraplegic and 1 quadriplegic) were discharged to a rehabilitation center and the remaining 2 patients had no functional neurologic recovery and were transferred to long-term care.

Overall the FAST was inadequate in 3.7%. Cardiac motion was demonstrated in 28.9% and pericardial fluid in 8.6%. A series of sensitivity and specificity analyses were completed starting with cardiac motion, adding pericardial fluid and finally the inadequate studies (Table 3). The sensitivity and specificity analysis of cardiac motion alone for identifying survivors or organ donors demonstrated a sensitivity of 100% and specificity of 73.7% (Tables 4–6). The Negative Predictive Value of cardiac motion on the FAST examination is, therefore, 100% with a Positive Predictive Value of 16.7%. The addition of pericardial fluid, or those with inadequate results did not improve the sensitivity for the identification of survivors or organ donors. All survivors and organ donors had an adequate view and all had evidence of cardiac movement on their FAST. The presence or

TABLE 3. FAST Findings in the Overall Study Population

	Total (n = 187)	Survivors/ donors (n = 9)	Deaths (n = 178)	P
Cardiac motion	54 (28.9%)	9 (100%)	45 (25.3%)	<0.001
Pericardial fluid	16 (8.6%)	0	16 (9%)	1.000
Inadequate view	7 (3.7%)	0	7 (3.9%)	1.000

FAST indicates Focused Assessment with Sonography in Trauma.

TABLE 4. Sensitivity and Specificity of Cardiac Motion in the Determination of Survival and Organ Donation

	Alive/ Organ Donation	Dead	
Cardiac motion	9	45	Sensitivity = 9/9 = 100%
No cardiac motion	0	126	Specificity = 126/171 = 73.7%

The seven equivocal studies were excluded from this analysis.

TABLE 5. Sensitivity and Specificity of Cardiac Motion or Pericardial Fluid in the Determination of Survival and Organ Donation. The Seven Equivocal Studies Were Excluded From This Analysis

	Alive/ Organ Donation	Dead	
Cardiac motion/fluid	9	60	Sensitivity = 9/9 = 100%
No cardiac motion/no fluid	0	111	Specificity = 111/171 = 64.9%

TABLE 6. Sensitivity and Specificity of Cardiac Motion or Pericardial Fluid or Inadequate Exam in the Determination of Survival and Organ Donation

	Alive/ Organ Donation	Dead	
Cardiac motion/ fluid/ inadequate	9	67	Sensitivity = 9/9 = 100%
No cardiac motion/ no fluid/adequate	0	111	Specificity = 111/178 = 62.4%

absence of pericardial fluid did not impact the sensitivity or practical utility of FAST in the arresting trauma patient. No patient in this study without cardiac motion or pericardial fluid survived or became an organ donor. In this study, had a FAST been used to select patients to undergo RT, all survivors would have been identified and more than half (59.4%) of the nontherapeutic thoracotomies would have been avoided.

DISCUSSION

RT is a high-risk, low-yield procedure that attempts to salvage patients who have sustained a traumatic cardiac arrest. Despite the risks inherent to the performance of this procedure[2,3] and the associated costs which include material costs, consumables such as blood products, human resources and resuscitation area occupancy which can ultimately impact patient flow throughout the hospital, patients do survive this procedure.[5–12,14,15,18,19,32] Although the dataare limited, long-term neurologic function of the survivors has also been documented, with intact cognition and acceptable rates of post-traumatic stress disorder.[17] In addition to survivors, another important outcome after RT is the potential organ donor. Despite all of the advances in transplantation science, every day in the US, more than 100,000 patients remain on the transplant list, many of whom will die before receiving a life-saving donation. In a study examining 263 RT patients, 4.2% became potential organ donors, and 1.1% ultimately donated, impacting the survival and quality of life of more recipients than the actual number of survivors[13] of the procedure. The actual survival rate does vary considerably because of the lack of uniformity in the indications utilized for RT in each of the studies, however, for certain mechanisms such as a cardiac injury, survival can be as high as 20%.[16] In a comprehensive 25 year review by Rhee that included 24 studies and 4620 cases, the overall survival rate was 7.4% with normal neurologic outcomes seen in 92.4% of survivors.[16] In this study, critical factors such as the location of injury (survival 19.4% for cardiac vs 10.7% thoracic versus 4.5% abdominal vs 0.7% multiple), mechanism of injury (8.8% penetrating vs 1.4% blunt), and signs of life (11.5% if present on arrival vs 8.9% if present on transport vs 1.2% if absent in the field) were found to be associated with survival. As in other studies, however, the authors concluded that "there was no clear single independent preoperative factor that could uniformly predict death."[16] Attempts to detect biochemical abnormalities[23] associated with survival have also been performed with the goal of finding correctable defects or predictors of futility, but these have also been unsuccessful.

Therefore, at this time, universally accepted guidelines[25–27] for which patients should or should not undergo RT do not exist. The comprehensive summary performed by Burlew and the Western Trauma Association Critical Decisions Group, highlights the lack of high quality data,[24] which is for the most part retrospective. In these retrospective studies where data- capture is difficult, key physiologic data elements and comprehensive mechanism and transportation data are often missing. Although more granular data can be obtained prospectively, these studies are uncommon and often limited by small numbers. Because of this, at this time there are no clinical predictors that are sufficiently strong to allow patients to be definitively excluded from this potentially life-saving procedure.

Ultrasound has been used extensively in the diagnostic evaluation of acutely injured patients. The FAST examination accurately detects the presence of free fluid within 3 body cavities, the peritoneum, pleural and pericardial spaces. It is a critical part of the contemporary management algorithm for penetrating injuries to the torso where the heart is at risk of injury. For patients in acute traumatic cardiac arrest, several preliminary retrospective studies have also highlighted its potential benefits.[33–36] It is an immediately available, rapid, repeatable, noninvasive point of care diagnostic modality that does not require the use of radiation. Although body morphology, soft tissue defects or abnormalities and user variability can impact the results, the views being utilized in this study are minimally affected and are technically simple to obtain. Two previous studies have specifically examined the ability of FAST to identify those who might survive a traumatic cardiac arrest.[34,35] In the study by Schuster,[35] 28 patients presenting with Pulseless Electrical Activity were examined retrospectively. FAST was utilized to examine contractile cardiac activity as a predictor of survival potential. Twelve of the 28 had organized cardiac activity on their FAST. Although all of the patients expired in this small series, those who regained a pulse and survived to leave the ER all had cardiac activity on their FAST. In the study from Cureton,[34] 162 patients in cardiac arrest were retrospectively examined. Survival was found to be 23.5% if cardiac motion was seen versus 1.9% if not, for a sensitivity of 86% overall and 100% for those arresting after penetrating injury. The absence of cardiac motion was found to be an excellent predictor of death with a NPV approaching 100%. This is further supported by the multicenter initiative by Moore that enrolled 56 survivors of RT over a 6 year period.[20] In this series, the largest to date, they concluded that RT was futile if asystole was the presenting rhythm and there was no evidence of pericardial tamponade. Our study is in agreement with this work. Cardiac motion was seen on the initial ultrasound of all survivors and organ donors. No patient that had absent cardiac motion or fluid survived, for a sensitivity of 100%.

The applicability of these results to other centers would rely upon the immediate availability of an ultrasound machine and a skilled user able to rapidly and reliably identify the heart and detect motion or pericardial fluid. This capability may not exist in all clinical settings. In particular, there have been several reports of prehospital RT,[37,38] predominantly in systems of care where advanced providers are brought to the injured patient at the scene. No such patients were enrolled in this study, although theoretically, if ultrasound capability was present on board the EMS transport, it could be used as a screening modality. In the larger context, alternative interventions such as REBOA are being investigated to better define their role in the periarrest period after trauma.[39,40] How bedside ultrasound is integrated into a management algorithm that includes both REBOA and RT will need to be further investigated. Even further into the future, the work being done on Emergency Preservation and Resuscitation[41] or suspended animation, may also increase the therapeutic options for patients in traumatic cardiac arrest. The screening diagnostic role of FAST in patients who may ultimately be candidates for Emergency Preservation and Resuscitation will need to be fully investigated. As a final consideration, from a societal perspective, the impact on provider training and team preparation of these findings must be considered. RT is already a relatively rare procedure. If the number of RTs performed is further decreased, especially in lower volume trauma centers, the trauma team may not accrue sufficient maintenance of skills, which may negatively impact the outcomes of a potentially salvageable patient treated by this unprepared team.

Termination of resuscitative efforts without opening the chest is an extremely difficult and emotional decision. The absence of cardiac activity, visible to the entire team, provides additional objective data that thoracotomy is futile and can aid in the decision to cease resuscitative efforts. This may be of particular benefit in those patients who fall outside the institutional or individual provider criteria in place for initiation of an RT. For these patients, these results may help mitigate an unnecessary waste of resources and potential harm to the providers.

In summary, for the patients that arrived to hospital and underwent a FAST examination, all survivors and organ donors had visible cardiac motion. If no cardiac motion or pericardial effusion was seen, the survival was zero. Ultrasound was, therefore, able to effectively identify those patients who had the potential to survive

the RT and discriminate them from those who did not. Utilizing ultrasound would have resulted in the avoidance of a significant proportion of thoracotomies which were ultimately found to be futile.

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DISCUSSANTS

D. Spain (Stanford, CA):

I would like to commend the authors on doing a prospective observational study with a fairly straightforward clinical question: can we use physician-performed ultrasound in decision-making for RT, which is a low-yield, high-risk, high-resource-intensive procedure.

I have five questions for you.

1. You said that FAST was performed by the emergency medicine residents. As a general surgery program director, I want to make sure that you are training your residents on how to perform ultrasound. Do you similarly train your general surgery residents on how to perform FAST?

2. The decision to perform the thoracotomy was made at the attending's discretion. Was there a big difference between your faculty? Do you have zealots and nihilists among your faculty in terms of RT?

3. In an article presented before this association in the 1950s, Arnold Griswold from Louisville documented a 77% survival for stab wounds to the heart. Clearly, mechanism is important. It's not just penetrating versus blunt; it depends whether it's gunshot wounds, stab wounds, or blunt trauma. Did you look at mechanism of injury as a predictor of outcome?

4. It's not just the RT. There is a lot of resources that go along with this. Can you tell us how much time and blood products were used in the nonsurvivors?

5. Finally, I think it's clear that we can use FAST to tell us when not to do a RT, but the positive predictive value of a FAST was only about 17% in your study. The number needed to treat was between 6 and 8, depending on how you count the survivors with devastating neurologic injuries. You would still have to do a fair number of resuscitative thoracotomies to get a survivor. I think it's clear that FAST can tell us when not to do it. I'm not so sure if a positive FAST tells us we should do it. Can you clarify?

Thank you for the opportunity to discuss these data.

Response From K. Inaba:

Thank you so much for those excellent comments. First of all, for the general surgery residents, yes, as a program director, I feel that this is very important, both for the residents and fellows. For the purposes of this study, however, because our residents were doing the thoracotomy, all of the ultrasounds were performed by the emergency medicine residents.

As far as the consistency of the indications, great question. We are a very aggressive group and uniform in our practice for patients who arrive in cardiac arrest. Virtually every patient underwent an emergency department thoracotomy. We did approximately 223 over a three-and-a-half-year time span, so very aggressive and consistent. Virtually every patient got one.

I agree that mechanism is very important when it comes to outcomes. Peter Rhee's study clearly delineated the importance of this. We did not look specifically at mechanism in this study, however, the one mechanism finding that did catch us off guard was that there were no patients amongst the survivors that arrested because of a cardiac stab wound, something that is usually quite common.

When we looked at this discrepancy more closely, what we found was that if a patient came in with a stab to the box, no matter what their blood pressure was, they were immediately brought to the operating room, which is 2 to 3 minutes, maybe not even, from our resuscitation area. In fact, of the 20-odd survivors of a cardiac injury during the study time frame because of a stab wound, seven of these, or a good third of them, arrested en route to the operating room or in the operating room on arrival. These are arguably patients that in many centers would have had a RT performed in the emergency department.

So, I think you bring up a great point. Mechanism is very important. The odd thing about our patient set is these missing stab wounds to the heart, but I think it is explained by the fact that they all went to the operating room and arrested there.

Should this tell us in whom we should do the procedure as opposed to those for whom we should not do the procedure? I think that's a great question. The positive predictive value is low, and practically I agree that the real value of ultrasound is not its positive predictive value, but in telling us who we probably should not perform the procedure in.

Finally, I think the resource question is critically important. I don't have an answer for you, but I agree, it's not just the room, it's not just the time, it's not just the disruption to patient flow, but there are true costs. Blood products for example are a major expense and although I cannot quantitate it for you, I agree that it is probably high.

P. Rhee (Tucson, AZ):

I want to keep this simple to just one question, and that's on the technique of the FAST. On these patients who come in, a lot of them, if not most of them, are undergoing CPR. When we stop that process, it's almost like I personally will hold my breath until we can get the procedure started, confirm that the person is dead, and get the procedure started.

So how long did it take for you to do this, and how much difficulty did you have in penetrating trauma injury, whether air in the chest affected the FAST and did you do it in the subxiphoid view or transthoracic?

Response From K. Inaba:

That's a great question. We obtained both a parasternal and subxiphoid window.

In the year leading up to the study start in October of 2010, we worked to get everybody onboard. It was an extremely difficult time, making sure every patient underwent an ultrasound. But by the end of a year, we were pretty happy with the compliance.

I don't have an exact time on how long it took, but to answer the practical question, was it performed and finished and recorded before the thoracotomy was completed, in the vast majority of cases, the answer is yes.

G. Moneta (Portland, OR):

In your presentation, it seemed like you were implying that maybe the data would be interpreted differently at academic centers versus smaller centers. I'm wondering whether you are implying that we should be teaching residents to do a futile procedure simply for their education. Is that correct?

Response From K. Inaba:

That's a great question. No, to clarify, I don't think that it is ever acceptable to perform a procedure just for its educational benefit. I do think it's a good collateral benefit of doing this procedure aggressively, but I don't think that we could ever do this procedure just for the educational benefit of residents.

At a smaller center, where it's not done routinely, and is not set up to perform this procedure immediately, I think it will be much more difficult to get the procedure going. There's probably also an increased risk of harm to the providers. I think this is what probably distinguishes a lower-volume center from a higher-volume center.

If somebody comes in in traumatic arrest to L.A. County, it's a very quick and efficient procedure. It's all set up and ready to go. The instruments are there. Everything is prepared. In a center that doesn't do this routinely, there's definitely a longer lead-up time, more of an impact on the other patients in the emergency department and there's probably more of a risk of harm to the providers. That was the distinction that I was making.

Finally, I do think that it's probably true that if we cut the number of resuscitative thoracotomies in half, an already rare procedure will become rarer. There will be an impact on training, but we should never be doing a procedure just for resident benefit.

F. Lewis, Jr (Philadelphia, PA):

Another variable that you did not examine but that is relevant to the survival rate is the prehospital time. In San Francisco, where I had a lot of experience with this, prehospital times were very short because geography is small. With that, the survival increases significantly. In a couple of articles that were reported from the San Francisco general experience a long time ago, the initial survival rate, for example, for myocardial stab wounds was around 40%, because they in fact had short prehospital times. I think that's worth factoring into your analysis.

The second thing, which I think is a much more obscure point, is that, as you showed here, the neurologic recovery rate, if the patients are resuscitatable, is quite high.

There's an initial period, typically for a few days to as much as a month, in which recent memory is lost. It's a very specific sign in these patients of the cerebral ischemia that occurs. Most other neurologic signs are not evident, but if you specifically test recent memory, it's gone for a few days in most of these patients.

The long-term outcome, as far as I know, has not been monitored by anyone because it's extremely difficult to get late follow-up. We actually had 2 examples of young people in their 20s when they had cardiac arrest who developed early dementia in their late 30s or 40s, approximately 10 to 15 years later, without other evident cause, suggesting that there was significant unrecognized neurologic injury as a result of the arrest that manifested in early dementia years later.

I think it's a point that I have not seen raised anywhere in the literature that actually needs to be thought about in this group of people and has not so far as I know been analyzed anywhere.

Response From K. Inaba:

That second question is a great point. There is at least one small case series with longer-term six-month follow-up, but, again, the data are very, very scarce.

In our patient series, about two-thirds of the survivors left the hospital neurologically intact from a cognitive perspective. Half of those had concurrent spinal cord injury, so they were not able to mobilize but they were neurologically intact. One-third were not neurologically intact.

We have no long-term data. Our patients are much like the ones in San Francisco, very difficult to follow up, so unfortunately we have no long-term data.

The prehospital times, or specifically the duration of CPR, I agree has been shown to be important in virtually all studies, including Gene Moore's study and the Western Trauma Association study. In fact, the 10- and 15-minute time limits for blunt and penetrating trauma based on these studies are commonly integrated into institutional protocols.

What we found in this study was that getting the exact time that CPR was conducted for was, in fact, very difficult even when we attempted to do so prospectively.

I think it's a great point. However, we found it very hard to delineate exactly how long this pre-hospital arrest time was, and because of the strength of the ultrasound findings, it ended up not impacting the results of our study. Thank you.