Establishment of Interdisciplinary Working Group for Review of Kinetic Energy Munitions
Final Report 2010

2005-MU-MU-K001

The project was supported by Award No. 2005-MU-MU-K001, by the National Institute of Justice, Office of Justice Programs, United States Department of Justice. managed by Joseph Cecconi, Senior Scientist. The opinions, finding, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the Department of Justice.

Contents

Background

Two distinct interdisciplinary review panels were formulated between 2006 and 2010: Behind Armor Blunt Trauma (BABT) review panel and the Less Lethal Technologies Medical and Scientific Advisory Panel (LLTMSAP). Each panel consists of members that have qualifications specific to the panel on which they are members. This report will be divided into two sections (BABT and LLTMSAP) with an overview of each meeting and a summary of findings.

Behind Armor Blunt Trauma (BABT)

Of approximately 1,200 officers killed in the line of duty since 1980, it is estimated that more than 30% could have been saved by body armor [1]. According to the James Guelff Body Armor Act, the risk of dying from gunfire is fourteen times higher for an officer not wearing a vest [1]. In addition, the US Department of Justice estimates that 25% of state, local, and tribal law enforcement officers are not issued body armor [1]. Since establishing the IACP/DuPont™ Kevlar® Survivors' Club® in 1987; over 3,000 law enforcement personnel have survived both ballistic and non-ballistic incidents because they were wearing body armor [2].

Body armor is comprised of fibers that have been woven together into sheets. Numerous sheets are used to make up one ballistic panel. The sheets work individually and together to help prevent the penetration of the bullet. Some materials that are used include: Kevlar®, Spectra® Fiber, Aramid Fiber, and Dyneema. The material fibers work to absorb and spread the energy over the entire torso so all of the energy from the impact is not focused on one area of the body, resulting in serious injury. Standards are set by the National Institute of Justice (NIJ) for the amount of deformation that is allowed into a person's torso, this is termed backface signature. With body armor becoming more pliable, more deformation is experienced and a certain type of injury has become more prevalent and is known as the backface signature injury. This is defined as an open wound that almost resembles a bullet wound, however, in these cases the bullet is captured in the armor and doesn't perforate the vest [3]. With these injuries becoming more common, the current standard for body armor should be evaluated to ensure officers are not at an increased risk.

In early 2000, National Institute of Justice [NIJ] and DoD were investing a significant amount of funding to lay the ground work for developing computer models to predict the injuries from LL devices. Much of the data being used to develop these finite element models were derived from animal and cadaveric data. Although many suspects were being exposed to LL devices, there were no human data available to validate these models. NIJ studied the issues surrounding the difficulties of obtaining human injury data, to include privacy issues, IRB issues, HIPPA issues, legal issues with potential law suits and many other regulations and sensitivities required to protect an injured person, their privacy as well as not compromising [and hopefully improving] the injured person's treatment. Exemptions were explored and a potential way forward was identified. It was then necessary to verify all regulatory and social issues and a pilot program was developed in order to verify all concerns. The pilot program was designed at NIJ and it was named the Less Lethal Incident Monitoring Program. It was to confirm that injuries and severity of injury data from LL device could be collected in a responsible, non-interfering way. If successful, these injury data could be used to assess the accuracy of the existing animal and cadaveric data and assist law enforcement and DoD in the verification of their computer models.

This program was successfully started and has recently yielded very interesting research reports in medical journals. It has also provided NIJ and the LL community with data to establish a formal baseline on the number of uses and their outcomes graded into three levels of injury severity. It additionally addressed the number one requirement, a methodology to obtain human injury data within all legal constrains.

This pilot on obtaining injury data on humans was revised to establish a methodology to obtain human injury data on officers that were shot while wearing body armor. With some minor revisions to the original Less Lethal Incident Monitoring Program pilot, a second pilot was begun, called the Body Armor Incident Monitoring Program. This pilot was designed to understand injuries to officers wearing body armor and to study blunt force trauma injuries (bruising, lacerations, and/or internal injuries caused by a bullet striking but not perforating the vest).

Study Methodology

Wayne State University and the IACP/DuPont™ Kevlar® Survivors' Club® have collaborated to determine the types of injuries that are likely to occur from a blunt impact to the chest and to determine if the current standard is effective at preventing serious injuries to the chest. Ballistic cases are identified by the Survivors' Club database. In addition to the Survivors' Club members, packets are also sent out to those that have been contacted by the Survivors' Club but have not joined. The packets that are sent include requests for their participation in the study, release of their medical records for that incident, and their contact information for a phone interview.

If the survivor agrees to participate, the medical records will be procured and a follow up interview will be administered over the phone. Also, to enhance the information received, police reports are also requested. All of the information collected is analyzed by a panel of experts.

Study Overview and Progress

All of the past ballistic cases from the Survivors' Club database have been contacted. As new cases enter into the Survivors' Club, packets continue to be sent to request their participation. Currently, 355 letters have been sent to IACP/DuPont™ Kevlar® Survivors' Club® members and 124 have been sent to potential members. A total of 77 have agreed to participate, 70 are members and 7 are potential members. Medical records have been procured for 50 cases. Follow-up interviews were conducted with 54 of the survivors'. In addition, to acquire more details from each of the participating cases, police reports are now being requested from the appropriate agencies. Nine police reports have been received to date.

RESEARCHERS

Cynthia Bir, Ph.D. – Co-Chair
Associate Professor
Department of Biomedical Engineering
Wayne State University

Duane Cronin, Ph.D.
Associate Professor
Department of Mechanical and
Mechatronics Engineering
University of Waterloo

Ian Horsfall
Professor
Head of Impact and Armour Group
Engineering Systems Department
Cranfield University, UK

Steve Champion
Impact Armour Group
Engineering Systems Department
Cranfield University, UK

Martin Raftenberg
US Research Laboratories

Edward Davis, Ph. D., MHS
Research Physiologist
Survivability/ Lethality Analysis Directorate
Army Research Laboratories

ADMINISTRATORS

Joseph Cecconi – Co-Chair
Senior Program Manager
Research and Technology Development
National Institute of Justice

Brenda Worthington
Technical Program Analyst
Lockheed Martin, NIJ Contractor

Daniel Longhurst
Firearms and Protective Equipment
Scientific Development Branch
Home Office, UK

Graham Smith, BSc (Hons), CPhys, MInstP
Manager: Police Weaponry, Firearms, and
Protective Equipment
Scientific Development Branch
Home Office, UK

Cathleen Higgins
Director of Law Enforcement Standards
National Institute of Justice

Steve Palmer
Executive Director
Canadian Police Research Center

Kirk Rice
Program Manager
Weapons and Protective Systems
Office of Law Enforcement Standards/NIST

PHYSICIANS

Mary Jo McMullen, M.D., FACEP
Senior Attending Staff Physician
Department of Emergency Medicine
Professor of Emergency Medicine
Northeastern Ohio University

Christopher Sloane, M.D.
Assistant Clinical Professor of Medicine
Department of Emergency Medicine
UCSD Medical Center

LAW ENFORCEMENT

Ronald McBride
Chief of Police (Ret.)
IACP/DuPont Kevlar Survivors' Club

Kirk Fitch
Deputy Chief of Police
City of Maricopa

Interdisciplinary Review Panel Meetings

As part of this process, a blue ribbon panel of experts was brought together to review the findings of the study. Prior to convening this panel, a meeting was held to give an overview of the project and to receive approval for the expert panel. The meeting included representatives from DuPont, IACP/DuPont™ Kevlar® Survivors' Club®, Wayne State University, NIST, NIJ, and two police officers.

The meeting was opened by providing an explanation of and a history pertaining to the IACP/DuPont™ Kevlar® Survivors' Club® database. This was followed by an overview of the National Institute of Justice Less Lethal program workflow that is being adapted to create the Body Armor workflow.

After the introductions and overviews, the current state of Wayne State Universities' project was presented to the panel. The purpose of the study, the data retrieving process, and the types of data being retrieved were described for the panel members. The purpose of the study was outlined as determining the types of injuries that are occurring while officers are wearing body armor. The data retrieval process was reviewed and includes sending letters asking for participation. With the return of the paperwork, including the medical release form and short survey, contact is made with the hospitals/doctors to retrieve the medical records and the survivors' to get their story. Officers with ballistic related injuries are the only ones that are contacted.

Suggestions were made to look at other data collection options than just the IACP/DuPont™ Kevlar® Survivors' Club® database to recruit participants. A possibility of contacting individuals that have been contacted by the Survivors' Club but have yet to join has been promised to help get more participants. Another suggestion that was made was to set up policies for the ER doctors to follow when a police officer arrives at the hospital.

Behind armor body trauma (BABT) panel meetings have been held to discuss the progress of the study. The panel is comprised of researchers, administrators, physicians, and representatives from the law enforcement community. Three meetings have been held thus far. Each participating case is looked over by the panel and discussed. Input is then generated by the panel members on how to improve the data that is received. A summary from each meeting is provided below.

BABT Panel Meeting Summary April 2007

The panel members that were present for this meeting included: Joe Cecconi, Cynthia Bir, Ron McBride, Ian Horsfall, Duane Cronin, Brenda Worthington, Daniel Longhurst, Cathleen Higgins,

Kirk Fitch, Mary Jo McMullen, Martin Raftenberg, Chris Sloane, Ed Davis, Sarah Stojsih, and Charlene Schreiner.

This was the first meeting that was comprised of the expert panel. On the first day of the panel meeting, an overview of the project was given. All the data that was gathered for each of the 56 cases was presented and discussed carefully. The data that was presented incorporated a synopsis of the incident, the threat level of the vest, injuries, and the caliber and type of weapon and ammunition. On the second day, the panel members were separated into subject matter expert (SME) groups to discuss each case individually. The SME groups were separated into researchers, administrators, and physicians. The final day was comprised of each group summarizing their thoughts and suggestions on what is needed to enhance the study**.**

The medical records were separated based on the threat level of the vest that was worn during the incident. Each SME group was designated a threat level, once discussions subsided, the records were passed to another group. The focus of the discussions included strikes to the armor and associated direct injuries, the coverage of the body armor, and the identification of cases that could be re-created in a laboratory setting.

The physicians looked through the medical records searching for indications of the quality of the exam that was given to the injured officers. Receiving complete medical records is crucial for this study, especially the ER report and the discard summary which include detailed information regarding injuries and treatment. The need for photographs of the injuries was also expressed during the meeting. This would allow verification of the severity and exact location of the injury. It was indicated by the end users that most police departments keep photographs of the injuries and of the vest. Another option would be to inquire about photographs of the injuries during the phone interview since some survivors' might have documentation of the injuries readily available. Discussions also involved the need for physician guidelines that ER physicians can follow when faced with an officer that had been shot. Stating tests that should be conducted depending on the shot location would be beneficial to the medical community. In addition, allowing the physician access to the vest that was worn by the officer could aid in the treatment. That way the treating physician would know where the impact occurred even if there wasn't a visual injury. In general, a portion of the medical records were incomplete and some were not helpful. More information is needed which can be obtained through the correct medical records or the phone interview with the officer.

The administrative group was focused on whether the armor, depending on the threat level and ammunition, was effective. However, they needed more specific information such as model numbers, detailed information about the weapons and bullets, and distances. The administrative group found from the cases that each threat level was well matched with the ammunition and was effective. There was no evidence of an over performing vest.

The researchers' focus was on cases that could be recreated and they discussed degradation from previous vest procurement issues. The researchers felt that in many cases there was a lack of detail that would make it difficult to recreate many of the cases. To get more information regarding each case, request of the police report may be helpful and should be considered.

Meeting Summary October 2007

The panel members that were present for this meeting included: Joe Cecconi, Cynthia Bir, Ron McBride, Steve Champion, Monique Exum, Graham Smith, Duane Cronin, Brenda Worthington, Daniel Longhurst, Kirk Fitch, Mary Jo McMullen, Chris Sloane, Kirk Rice, Ed Davis, Sarah Stojsih, and Charlene Schreiner.

The second BABT panel meeting was a two day meeting in conjunction with the IACP Conference. With fewer cases to discuss, the panel was able to take each case, one-by-one, and have an open floor discussion among all panel members. Thirteen cases were discussed on the first day. Six of the cases discussed were new cases that were received after the last meeting. The remaining seven cases were discussed during the last meeting in April; however, new information was received since and needed to be addressed. The second and final day was a chance for the panel members to present their individual ideas and suggestions for the future of this study.

The new medical records and cases were reviewed and then discussed by the panel. In addition, as suggested the last meeting, police reports were requested. Two police reports were reviewed and discussed by the panel members. Schematics of the crime scene that were included helped the panel visualize what happened and how a recreation could be accomplished. It was determined that the schematics could potentially be very helpful for recreations and should be requested when available.

The second day consisted of presentations by Mary Jo McMullen, Chris Sloane, Brenda Worthington, Kirk Rice, Edward Davis, and Duane Cronin. Mary Jo McMullen described the need for a website that instructs physicians on how to treat an officer with a blunt trauma to the chest. The website would also capture the victim as an incident for the study and the Survivors' Club. In addition to the website, a tag should be adhered to the vest that reads "If shot take this vest to the emergency room." This is important because the ER physicians need to look at the vest to see where the impacts occurred. There are a few cases were the physician did not know the officer was shot in the chest because he/she had their body armor on and the bullet did not penetrate. However, the area should be evaluated since there was a trauma that occurred. She also addressed the need of getting the information out to the public either through law enforcement sites, TechBeat, PoliceOne, etc.

Chris Sloane added to the ideas of Mary Jo McMullen. He suggested another idea on how to obtain vests and medical records for this study. If the NIJ would approve and fund this idea, we could issue a new vest to the survivor in exchange for the old vest and medical records. A

request could also be made to get the manufactures involved with the risk of getting only the data that they want to give.

Brenda Worthington expressed interest in developing a "red team" to identify shootings. She also discussed looking at insurance claims and Workman's Compensation for new cases that can be added to the study.

Kirk Rice went through the testing of body armor using the Thoracic Impact Membrane (TIM). The TIM measures deformation or displacement of the thoracic cavity with the help of lasers. He discussed the potential for using clay initially to look at the deformation created and then compare clay data to data collected using the TIM. This could also serve as certification of the TIM. However, there are some limitations to this system. It may not be a good method of determining the localized injuries because it will not generate the risk of skin breakage or perforation.

Edward Davis discussed the history of body armor research and collecting field data in the military. Vietnam was the first effort at collecting field data regarding injuries and within the last 2-3 years there has been a major increase in the amount of data collected. The 3-D Computer Man Anatomical Model was also discussed. This model allows the user to input a scenario which generates the injuries sustained. The model is based on field data that has been collected about injuries recorded by the Armed Forces. The AIS and severity scores can be determined as well as physiological responses.

Finally, Duane Cronin discussed his research on improving the vest design based on blast type wave testing. He has been focusing on hard plate armor for his research. The thought is that there might be more blast type waves through the body that do not occur with soft armor. There is a need for data from animal, cadaveric, and computer models to obtain a complete picture.

Meeting Summary November 2008

The panel members that were present for this meeting include: Joe Cecconi, Cynthia Bir, Ron McBride, Steve Champion, Steve Palmer, Graham Smith, Daniel Longhurst, Kirk Fitch, Chris Sloane, Kirk Rice, Sarah Stojsih, and Charlene Schreiner.

Prior to the third meeting in November, an article was published in the Summer 2008 edition of TechBeat. The article was written to bring awareness to the research being conducted by Wayne State University and the IACP/DuPont™ Kevlar® Survivors' Club®.

The third BABT meeting was held in two days, prior to the IACP Conference. During the first day, 6 new cases, 4 police reports, and previously discussed cases with additional information were reviewed. Additionally, key cases were identified in previous meetings. These cases will be reproduced in the Ballistic Laboratory at Wayne State University. Prior to this meeting, one key case was re-created and the data was discussed with the panel.

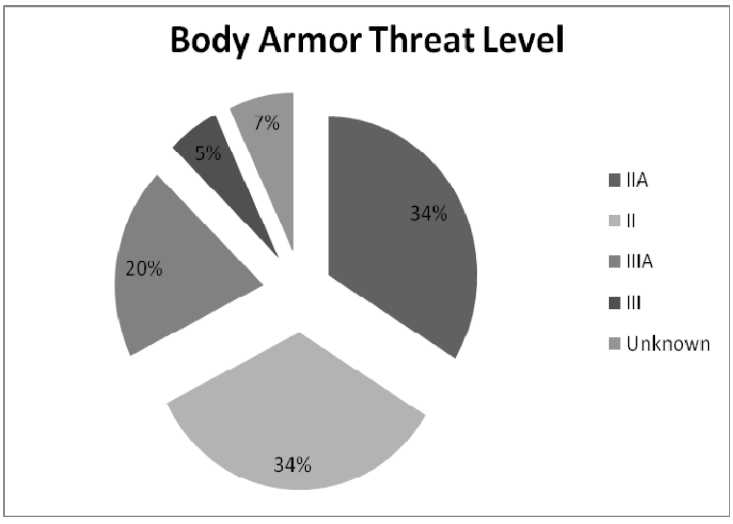
On the second day of the panel meeting, four future directions of the project were discussed. The first topic that was discussed involved starting a physicians group. The goal of the physicians group would be to get the data out to the emergency groups and suggest guidelines for treating an officer that had been shot. The second subject that was discussed was how to obtain used vests for the re-creations. The best option would be to ask the officer if he/she had the vest and to use the back panel if it was available. Also, using Kirk Fitch as a law enforcement liaison may aid our efforts to obtain more police reports and other important information. The third topic discussed included how to get more cases since we have contacted all potential participant from the Survivors' Club up to this point. Possibilities included online sources, news media, and the NEISS database. This might also allow us to get participants faster, in turn, obtaining more accurate data. The final point that was discussed was with regard to the Survivors' Club application form. Some of the panel members will be meeting in early February 2009 to discuss improvements for the application. Suggestions were made by all the panel members.

Overview of Data Collected

Of the 77 cases collected, 71 had adequate data available. Data for each case were obtained through phone interviews, medical records, and police reports. Injured officers were between the ages of 22 and 54, with the average being 34±8 years of age. From the 71 cases that were collected for this study, there were a total of 90 shots stopped by personal body armor. The majority of the shots impacted the anterior chest (74%, n = 65), followed by abdomen (16%, n = 12), posterior upper torso (9%, n = 8), and posterior lower torso (6%, n = 5).

The level of protection offered by a ballistic vest is an important element of officer safety. The NIJ body armor performance standard has been revised several times since its inception to reflect the growing threats faced by officers. Vests are certified using a combination of weapons and rounds that are commonly used by law enforcement and criminals. The most current standard classifies armor into 5 types: IIA, II, IIIA, III, and IV. The first three levels are soft armor that protect against various handgun and shotgun ammunitions, while the last two levels are hard plates used in conjunction with soft armor to protect against rifle and armor piercing rounds. The majority of officers in this study wore either a threat level IIA or II vest (Figure 1). From all of the cases, 25% of the officers had additional protection from a trauma plate or pack.

Figure 1: Percentage of body armor threat levels based on case studies



The injuries that occurred from the 90 shots stopped by the armor have been classified as blunt trauma and backface signature injuries (Table 1). The majority of the injuries resulting from impacts to the vest were categorized as blunt trauma injuries (60%, n = 54). These include less severe injuries involving contusions, abrasions, and rib fractures. Backface signature injuries were the next most common injury among the sample population (21%, n = 19). Eleven of the impacts to the vest resulted in no notable injury (12%). Four impacts struck the edge of the vest and resulted in a gunshot wound (4%) and the remaining 2 impacts generated injuries that were unknown (2%).

Table 1: Summary of case study data.

	BODY ARMOR THREAT LEVEL				
INJURIES	**IIA**	**II**	**IIIA**	**III**	**Unknown**
Chest Blunt Trauma	11	18	6	1	3
Chest BFS	7	2	2	1	2
Abdominal Blunt Trauma	5	1	3	-	-
Abdominal BFS	-	1	2	-	-
Posterior Torso Blunt Trauma	1	3	-	1	1
Posterior Torso BFS	1	-	1	-	-
Edge Shot – GSW	2	1	-	1	-
No Injuries	5	3	3	-	-
Unknown	1	-	1	-	-
Total	33	29	18	4	6

Typically a blunt trauma injury is defined as mild to severe contusions and abrasions. In addition, rib fractures, liver lacerations, and lung contusions may also present themselves. Four officers sustained rib fractures, 1 officer experienced a lacerated liver, and 1 officer was found to have micro-fractures of the ribs and a lung contusion from impacts stopped by their protective vest.

Case Re-creation

Key cases that were identified during panel meetings have been mimicked in a laboratory setting to obtain backface signature depth to compare to injury severity. Through the use of medical records, phone interviews, and police reports, detailed information was collected on what type of firearm was used in the assault, what manufacturer, model and threat level of vest was worn, a detailed account of the incident, and information about the injuries themselves. If available, photographs of the injury and/or vest were obtained. Three cases have been re-created thus far.

Backface signature testing was conducted using a clay medium based on the NIJ 0101.06 [4] and HOSDB Body Armour Standards [5]. Roma Plastilina No. 1 clay was conditioned and calibrated according to the NIJ Standard [4]. To capture velocity data, a chronograph and high speed video were used. The depth of

the resulting back face signature was measured using digital calipers and the volume was determined using a premeasured volume of water.

Tables 2 and 3 summarize the specific details of each of the 3 cases. This information was obtained from medical records, police reports, and phone interviews. The data provided by the officers was replicated by the lab as closely as possible (i.e. bullets, shot angles, armor type, etc.). The only discrepancy occurred for Case #2; while the caliber and manufacturer of the bullet used were known, the weight and bullet type were unknown. At the time of the testing an ammunition shortage was occurring, therefore, the round obtained was the only readily available Winchester 357 Magnum.

Table 2: Ballistic details for each case study

Case	1	2	3
Weapon	Glock 22	Ruger Revolver	Glock 17
Ammunition	40 S&W Federal Premium 180 grain HP	357 Mag. Winchester	9mm Luger Magtech 124 grain FMJ
Vest	Safariland Zero G Threat IIIA	Point Blank Model 20XT Threat II with steel plate	Vestguard UK

Table 3: Injury details for each case study

Case	1	2	3
Recovery Period	3 months	None	2 months
Time off Work	3 months	None	2 months
Degree of Injury	Superficial Laceration, Contusion, and Abrasion	Redness and Swelling	Laceration and Contusion
Long Term Effects	None	None	Tender Area

Case Study #1

The incident occurred in July 2006 and involved a male officer, 34 years of age, 170 cm (5’7”), and 84 kg (185 lbs). While conducting a traffic stop, the officer realized the driver had a warrant out for an unrelated matter. The officer ordered the driver out of the car; a struggle ensued leading to a foot pursuit. The

officer overtook the assailant and a second struggle ensued. At this time the assailant gained control of the weapon belonging to the officer's partner. The assailant shot the officer once in the upper right torso. The injury occurred approximately 5 cm (2 in) below the right nipple and 1.3 cm (0.5 in) toward midline. The assailant was 30 to 60 cm (1 to 2 ft) away and was standing directly in front of the officer when the shot was fired. The officer suffered a contusion and abrasion to the right chest wall. The ecchymotic (bruised) area was approximately 6x6 cm (2.4x2.4 in) in size. Active bleeding was noted as well. The contusion lasted approximately one month and there have been no long term effects. Photographs of the injury were not available.

Case Study #2

The incident occurred in February 1997 and involved a male officer, 40 years of age, 183 cm (6'0"), and 86 kg (190 lbs). The officer was responding to a carjacking incident. The officer and his partner spotted the stolen vehicle and a number of suspects surrounding the vehicle. The suspects noticed the patrol car and took off on foot. Hoping to intercept the suspects, the patrol car went around the corner. The officers saw the suspects and the participating officer exited the patrol vehicle in an attempt to apprehend one suspect that had fallen to the ground. However, the suspect ran around a corner into a poorly light area where the suspect turned and shot the officer. The round impacted the officer's left anterior chest wall. The round penetrated the metal plate the officer was wearing but not the vest. The suspect was approximately 3 m (10 ft) from the officer and the path of the bullet was perpendicular to the torso of the officer. The officer suffered an 8x8 cm erythematous (redness) area over the left anterior chest wall (Figure 2). Swelling of the area occurred but there was no bleeding and no long term effects. Since the officer's vest carrier was available for our analysis, the exact location of the bullet on the vest was known.

Figure 2: Photograph of the injury sustained by the officer in Case #2

Case Study #3

This case occurred in the October 2008 and involved a male officer, 45 years of age, 178 cm (5'10"), and 90 kg (198 lbs). The incident occurred during daylight, but happened indoors. The

officer was approximately 10 m (33 ft) from the suspect when the weapon was fired. Additional details regarding the case are classified. The round impacted the officer's right anterior chest. The officer suffered a contusion and open wound with active bleeding (Figure 3). Long term data is not available since it occurred roughly one year ago. Currently, the officer still experiences tenderness of the area. As in Case #2, the officer's vest was available for our analysis and the exact location of the bullet on the vest was known.

Figure 3: Photograph of the injury sustained by the officer in Case #3

Backface Signature Testing and Vest Damage

For a vest to be certified by the NIJ 0101.06 Standard, the backface signature in the clay material must be less than 44 mm, for HOSDB this can be either 44mm or 25mm dependant on level of armor. In addition to testing the backface signature using the clay backing material, the effects on the vest were also noted. A summary of the results are listed in Table 4. Unfortunately the volume of the crater was not recorded for Case #1. Figure 4 illustrates the craters that were created for the different cases.

Table 4: Experimental results from each case re-creation.

Case	**1**	**2**	**3**
Velocity (*m/s*)	335	449	354
Depth of Backface (*mm*)	31	14	25
Volume of Backface (*mL*)	-	18	38

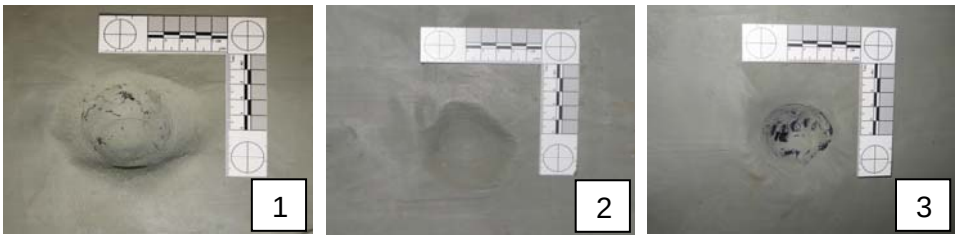


Figure 4: Clay indentations for Cases #1, 2, and 3.

Following inspection of the backface signature, the damage to the vest and its layers were noted. For Case #1, the round did not penetrate any of the layers of the vest; however, there was mechanical damage

to the first and second layers. Case #2 involved a metal plate on the outside of the armor. The round penetrated the metal plate but did not penetrate the armor. Minimal mechanical damage was caused to the first layer. For Case #3, the vest that was worn during the incident was the same vest that was tested. During testing the shot was taken on the opposite side (left side) of the front panel and slightly lower than the original shot. This was done to insure that the damage from the original shot would not interfere with the testing. When inspecting the vest, the bullet had penetrated the first layer of material and had caused mechanical damage to the second and third layers. This result is consistent with the damage caused by the original shot.

Summary Observations from Panel

Medical Issues

- When an officer is shot in the area that is covered by body armor, the injury will not always be obvious. So if possible bring the body armor to the hospital so the emergency physician can inspect the armor hence, making them aware of all shots the officer sustained.
- Due to infrequent occurrences, there are no formal guidelines to help emergency room physicians diagnose or treat these specialized wounds. Panel members are putting together draft guidelines to address this item.
- These guidelines need to be made available to Emergency Room doctors. The panel is exploring ways to distribute this information.
- A suggestion was made that even if there was no major injury visible after the shooting, that the officer still seeks medical attention due to the forces that could couple into the body causing internal injuries.
- Label the vest with a website that can be accessed to obtain latest info on medical treatment for this specific injury. Additionally, this website can contain information on how to collect information on the event so that this incident can be analyzed.

Psychological Issues

- The panel is aware of the psychological trauma from such a harrowing event and the amount of time necessary to recover after such an incident. This trauma may go beyond the work setting and includes the family. This panel does not have the expertise to address the psychological aspects of such an event hence, is recommending that another study with the appropriate expertise on the panel addressed the psychological trauma.

Research Issues

- It is felt that the resource of the IACP Survivor's Club database has resulted in several good cases, however additional data from this resource will be limited in the future. There is a need to identify other resources to procure case studies. Options of mailing specific larger agencies through the State Association Chiefs of Police are being explored.
- For this study ballistic information is very important. Also, having records regarding the type of bullet (caliber, grain, FMJ, HP, SP, etc.), weapon including barrel length, and distances between the officer and shooter are very critical when assessing injury.
- The panel is trying to determine how to obtain the information that occurs within the first hour of the event. Items such as the distances, location and positions of the shooter and officer, how the vest was fitted on the body of the officer at the time of the shooting and if a number of shots were fired, the whole sequence.
- Educate law enforcement officers about the proper fit of body armor and how to care and maintain it.
- The vest label can be used to sample vests in the field. By putting a return to date on the vest, this vest can be sent to a testing facility. To insure compliance, the owner could get a new vest at a significantly reduced cost.
- Better labeling of vest was recommended so should an incident occur details about the vest could be obtained.

Accomplishments

All of the past ballistic cases from the Survivors' Club database have been contacted. As new cases are entered into the Survivors' Club, packets will continue to be sent to request their participation. Currently, 355 letters were sent to IACP/DuPont Survivors' Club members and 124 were sent to potential members. A total of 77 have agreed to participate, 70 are members and 7 are potential members. Medical records have been procured for 50 cases. Follow-up interviews were conducted with 54 of the survivors'. In addition, 9 police reports have been received to date. Twenty-four key cases have been identified by the panel and reproduce will be attempted.

During data collection additional parameters have been identified. First, guidelines for the medical community regarding treatment options are needed. A physician's panel will be created to address this issue. Second, there are a number of key cases that are lost due to insufficient data. Mainly the need for similar vests that could be used during a reproduction of the cases was identified. An option to collect this data could be with the development of a vest exchange program where the vest would be purchased or voluntarily given to researchers for testing purposes. Finally, the need for psychological data collection was recognized. Since this is a sensitive topic, an additional panel of experts may be created.

A sub-panel of physicians has been formed to address the need identified in regards to medical care received by police officers after being shot while wearing body armor. This sub-panel consists of Chris Slone (UCSD Medical Center), Mary Jo McMullen (Northeastern Ohio University) and Alexander Eastman (Dallas Police Department, SWAT). The goal of this sub-panel will be to establish guidelines for treating officers and to develop a dissemination strategy.

A group of panel members (Cynthia Bir, Sarah Stojsih, Kirk Rice and Joe Cecconi) also met with representatives from IACP to discuss updating the current Survivor's Club survey. This meeting was conducted in an effort to streamline the survey and discuss ways to more effectively gain access to the data.

An article was written for the Summer 2008 edition of TechBeat. The article describes the ongoing efforts of this study and was written to bring awareness to the law enforcement community. The article is attached at the end of the report. Additionally, abstracts were submitted to AAFS, ECPC, and PASS and were accepted to all three conferences. A manuscript summarizing the entire field data collected will be submitted to Journal of Trauma by September 2010.

References:

1. Guelff, J and McCurley, C. Body Armor Act of 2001. House Report 107-193
2. IACP/DuPont Kevlar Survivors' Club [accessed February 11, 2009]; Available at: http://www2.dupont.com/Kevlar/en_US/uses_apps/law_enforcement/survivors_club.html.
3. Wilhelm, M. and Bir, C. Injuries to law enforcement officers: The backface signature injury. Forensic Science International. 2008. 174: 6-11.
4. National Institute of Standards and Technology. Ballistic Resistance of Body Armor, NIJ Standard 0101.06. 2008. NCJ 223054.
5. Home Office Scientific Development Branch Body Armour Standards for UK Police, Publications 39/07 A, B & C, 2007.

From Summer 2008 *TechBeat*

Body Armor – Don't Leave Home Without It!

Making his best attempt to catch the bad guy, a police officer rounds a corner into a dark alley unsure of what lies ahead of him. Suddenly, the dark alley was brought alive by the flash and explosive energy of a .357 revolver. The officer was shot once in the chest, an unfortunate consequence of being a police officer. However, because the officer had on his personal body armor, he got up and walked out with a bruised chest….and his life.

Since the International Association of Chiefs of Police (IACP)/DuPont™ Kevlar Survivors' Club® was established in 1987, more than 3,000 individuals working in law enforcement have survived both ballistic and nonballistic incidents because they were wearing body armor. Of the approximately 1,200 officers killed in the line of duty since 1980, more than 30 percent might have been saved if they had worn vests.

A study conducted by the FBI in 1994 estimated that an officer not wearing body armor has a risk of dying from gunfire that is 14 times greater than for officers who do wear armor. In 2003, the Office of Justice Programs' National Institute of Justice (NIJ) developed a pilot program to assess injuries caused by less-lethal devices in the field in near real time. In 2006, NIJ evaluated the usefulness of this framework for understanding injuries to officers wearing body armor, and subsequently decided to fund a pilot study focusing on blunt force trauma injuries (bruising, lacerations, and/or internal injuries caused by a bullet striking but not penetrating a vest).

Although final study results will not be available until 2009, some preliminary conclusions have been drawn:

- When an officer is shot in an area covered by body armor, resulting injuries will not always be obvious. Bringing the body armor to the hospital may help the emergency physician diagnose injuries. Even if no injury is apparent in the wake of a shooting, the officer should still seek medical attention because of the possibility of internal injuries.
- Accurate records about ballistic information (including caliber, grain, and barrel length), as well as the distance between the officer and shooter, are also key in assessing injuries. These records and other information such as how the vest fit at the time of the shooting, number of shots, and shot sequence should be collected within 15 minutes of the incident, or much of this information can be lost.
- Because of the infrequency of officer shootings in most communities, formal guidelines to help emergency room physicians diagnose or treat blunt trauma injuries do not exist. An international panel of experts that is analyzing results of the study is compiling draft guidelines to address this and exploring ways to distribute this information to hospital emergency rooms.
- A tag on the vest that leads to a website that provides the latest information on medical treatment for blunt trauma injuries could prove a great asset to the medical community, as could an Internet resource on how to collect information on the event for later analysis.
- A recommendation that after an event, even if there is limited visible bruising, the officer seek medical attention in case forces were propagated into the body.

- Events of this type also cause psychological trauma and may require long recovery times. Also, the incident's effects may extend beyond the workplace to include the officer's family.

The international panel of experts that is performing the review and analyzing incidents is co-chaired by Dr. Cynthia Bir of Wayne State University and Joe Cecconi of NIJ. The Survivors' Club collaborated with Wayne State University to determine the types of injuries likely to occur. Emphasizing injuries sustained and possible long term health effects, the panel is reviewing actual field data to determine what injuries occurred, estimate their severity, and analyze whether injuries are being fully assessed. The 65 participants, who agreed to release their medical records and contact information for the purposes of an interview, were drawn on a volunteer basis from members of the Survivors' Club.

The panel is reviewing, discussing, and analyzing each participating case, and generating input on injuries sustained and ways to improve the care the officers received. The panel will also examine better ways of collecting data. Surviving officers participate in discussions and recount their own personal experiences, giving the panel a broader understanding of the incidents, the overall care received, and the recovery process.

The panel will continue its work throughout 2009. The researchers want to thank the volunteers who participated and are looking for more volunteers who are still interested in having their cases reviewed.

For more information, or to volunteer to participate, contact Joe Cecconi, senior scientist, Office of Science and Technology, Operational Technologies Division, National Institute of Justice, at 202–305–7959, joseph.cecconi@usdoj.gov; or Cynthia Bir, Ph.D., associate professor, Wayne State University Biomedical Engineering, at 313–577–3830, cbir@wayne.edu.

Less Lethal Technologies Medical and Scientific Advisory Panel (LLTMSAP)

Law enforcement personnel rely on less lethal weapons as an alternative to lethal force in situations with an individual or as a method of crowd control. However, as the use of less lethal alternatives has increased, the likelihood of severe or even fatal injuries has increased as well. Currently, it is the responsibility of the manufacturers and the end users to determine whether or not the risks are appropriate. The ability to assess the prevalence and associated severity of injuries due to less lethal impacts is essential to ensure that these weapons are not producing undesired effects.

The use of case studies is one essential piece in understanding the health effects of less lethal munitions. An effort is currently underway to garner such information (Bozeman, 2004). Such knowledge can then be applied to assist in the planning of clinical care, validate existing models and provide information to the end users for use in critical field deployment decisions. A multi-disciplinary approach was undertaken to ensure that a thorough review of each incident was conducted. Through the use of both experimental and epidemiological data, a thorough understanding of the health effects and recommendations for future development and use of less lethal weapons is possible.

The effort conducted by Wake Forest provided the foundation for the establishment of the Less-lethal Tactical and Medical Scientific Advisory Panel (LLTMSAP). The aim of this panel is to minimize risk to general public, to law enforcement officers and agencies with respect to less-lethal technology. The panel will provide independent expert review of information related to less-lethal technologies including pre-deployment safety and operational data assessments as well as post-deployment incident review. This information will be provided to policy and decision makers through the NIJ.

A total of three reviews were conducted by this panel during this grant period. The first involved a review of interesting Conducted Energy Weapon (CEW) cases that were presented by co-investigators of the Wake Forest Less-lethal Incident Review. The second involved the review of a new technology that was being considered for correctional facilities: Assault Intervention Device (AID). And the third was a review of a launched 12-gauge CEW device; the eXtended Range Electronic Projectile (XREP).

CEW review

The goals of this first meeting included a review cases from all study sites, definition of future meeting and data collection processes, suggestions for research that should be funded, and thoughts/comments on using the network as a beta site for new devices.

Presentation was given by W. Bozeman regarding the current Wake Forest Less-lethal Incident Database effort. It was pointed out that conducted energy weapons (CEW's) are the most

studied weapon in history from a safety standpoint and a lot of the research has been conducted on human volunteers

Information was provided that showed that the results in volunteer studies may not reflect risks in population of interest because of: medical/psychiatric history, medication, illicit drug use, health history. The current data has come from a variety of places including: voluntary reporting database (Taser International), police administration data, and medical reports (still need large data collection/multi-center).

The current effort presented by W. Bozeman included definitions of injury severity: mild, moderate, and severe. Over 1201CEW uses have been collected over 3 years (2005-2008). Information collected about each case included: demographics, deployment patterns, discharges, body impact areas, and injury details. Primary results were presented with injury details. Two in-custody deaths were reported.

A summary of the CEW safety and medical effects based on the Wake Forest study were presented. W. Bozeman felt the safety profile was excellent and that significant injuries to be rare but can occur. It was reported that medical or psychiatric conditions may cause behavior that leads to police involvement.

Discussions were held in relation to the current public perception of the CEW use in Canada and the issues faced by the Canadian police. It was stated that Toronto and Vancouver are the only areas with forensic medical physicians. In addition, the Canadian Police Research Center (CPRC) has collecting information in key areas (Calgary, Victoria, Edmonton, and Quebec City) and has been writing technical reports to get around the lengthy medical journal process. The data collection methods consist of a one page form to fill-out (in Calgary forms filled out electronically in cars, in Victoria some electronically in cars/some paper, everywhere else paper) with access to medical records only granted in pre-arraigned locations.

Statistics were presented from the data collection efforts in Canada. Data included: de-identified officer injuries, what percentage of suspects were injured (went to hospital), and what percentage of officers were injured based on combat weapon. An effort was also presented which involved the use SCAPGAS to get blood gases on the scene. Current efforts were underway to work on validating the process with the next effort being field testing. The focus was to be on cases of excited delirium.

Each site investigator present at the meeting, presented cases from their regions that demonstrated the unusual cases. Discussions were held after each presentation. Some of the general comments included the current research and safety testing being conducted and the need for continued monitoring. Some key action items were identified including: providing a training

program websites to various groups, prepare manuscript on ED pre-hospital treatment, evaluation and testing of new technologies through established network, need to bring in criminologists to the panel, phase-in other less-lethal incidents, add additional sites for research data collection and establish best practice guidelines for less-lethals.

Assault Intervention Device (AID)

This panel was brought together for a second meeting to review a new less-lethal technology called the Assault Intervention Device (AID) prior to its deployment in a real world scenario. The AID is a directed energy system that emits millimeter wave energy at a frequency of 94 – 95 GHz. The beam density and duration is automatically regulated to directly deliver a total "dose" of no more than 12 J/cm^2 to an intended target or bystander (Figure 1). A significant body of health effects research has been performed in animals and humans using similar systems that also emit millimeter wave energy at the same frequency, with the same or greater total power delivery.

Animal research has been performed in mice, rats, swine, and nonhuman primates to evaluate a number of potential health effects. These have been performed using total doses at or in excess of the system under consideration. These indicate that there is no significant risk of moderate or severe skin or eye damage at the power levels under consideration.

More than 11,000 human subjects have received millimeter wave energy at or above the power levels under consideration. Directly related minor injuries such as erythema (redness) or small skin blisters have occurred in 21 subjects, a rate of 0.19% (95% confidence interval 0.12% to 0.29%.). All of these healed within 24 hours without long term effects. This translates to a maximum of approximately a 1 in 350 chance of a subject sustaining similar minor skin effects.

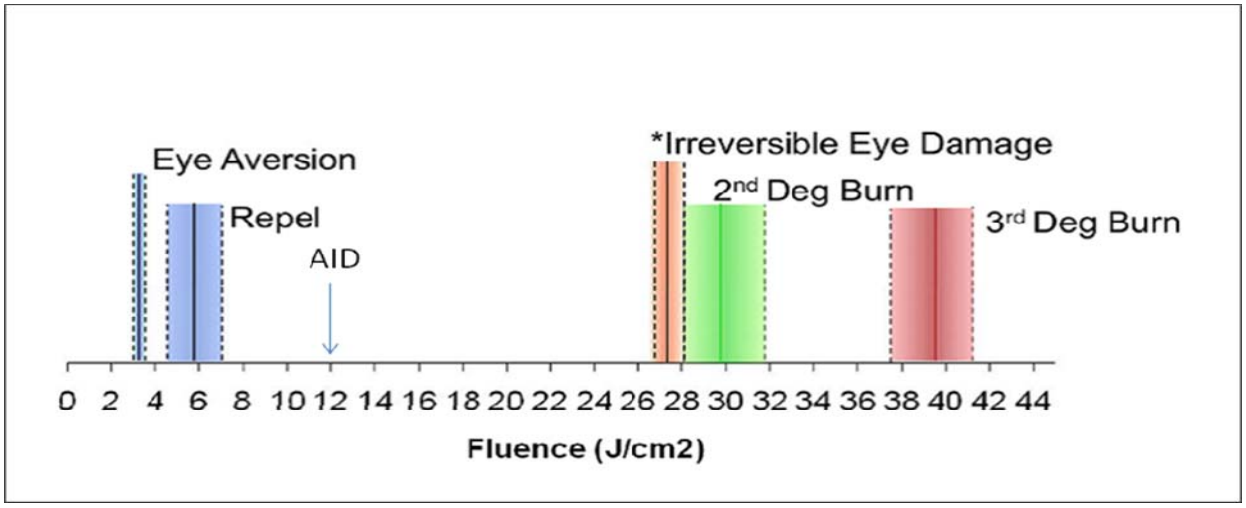


Figure 1: Response based on Fluence (J/cm^2).
* might occur if normal blink and head turning response were prevented.

A single case of a moderate injury occurred in one subject during human testing. In this case a human error led to inadvertent exposure of 5 times the intended dose and an 8% total body surface area burn occurred. The system under consideration is automatically regulated without human input; a similar event is highly unlikely in the absence of a major equipment or software malfunction.

While there are no characteristics of the waveform that should induce carcinogenic activity, the research on carcinogenic outcomes is too limited to claim the safety in this area that is suggested by the manufacturer. Simply put, there is currently a lack of data regarding long term effects and a longer post exposure monitoring period is required before definite conclusions can be drawn.

Shortcomings that should be considered but generally do not exceed benefits of system.

The biggest concern expressed by the committee is the lack of real use data and limited presentation of data by the manufacturer. Despite these factors, given the data that was presented, along with knowing the mechanics of this device and the pathophysiology of illnesses such as cancer and burns, this appears to be of very low risk to the individual.

The previous human exposures were performed in controlled conditions, and do not provide information on certain other risks. Most importantly, these include a theoretical risk of secondary injuries, i.e. falls, due to reflex motion or poorly executed attempts to leave the area of the directed energy beam. Other limitations include incomplete characterizations of effectiveness and risks specifically related to the smaller beam size of the system under consideration and conditions in which it may be used. These include reflected beams resulting in a "multipath" exposure of greater than the intended power delivery. These risks are felt to be minimal.

Shortcomings that can be addressed with policies, procedures and training

Based on the information provided to the committee, there were minimal shortcomings or risks, as even the risks of over-exposure to skin and eye damage should be minimized in the awake individual. Provided the device has a failsafe that functions 100% of the time, the risk to skin seems minimal, and perhaps even training the operator to redirect the beam to lessen the effects if the system malfunctions. There persists a small risk to eyes in the unconscious person, particularly if the beam bounces off surfaces, but again the risk seems minimal and may be at least partially mitigated with training.

The committee feels it will be profoundly important to systematically and prospectively document: a) the nature of any exposure: nature of the situation, number of inmates proximal to the beam, demographics of inmates proximal to the beam, direct targets of the beam, duration of exposure and settings of the unit at the time b) the outcome of that exposure: successful dispersion of inmates or unsuccessful dispersion and the reasons why c) the effects of the

exposure: there must be a mandatory medical exam if at all possible, while the inmate may always refuse medical care, the medical exam should be offered as a post exposure standard and refusals should be documented, d) early and late complaints about physical effects should be documented with sheets for documentation including all anticipated effects (eyes, skin, etc).

The rationale for this documentation is not to study and outcome, but rather to allow the agency (corrections) to document that the system was used appropriately, had the desired effect and is being monitored to ensure that the system characteristics really do perform in the way that the manufacturer suggested it would.

Shortcomings of the system that increase risk beyond current methodologies of problem management

The biggest shortcoming identified by the panel is the lack of real-world use and unknown avoidance techniques. To the knowledge of the panel, this device has not been used against an aggressor to make them stop their behavior. It has only been used against willing volunteers told to act like aggressors. While this is a reasonable first step, we cannot be certain what effects it will have in this new group. When one considers the risk of using this device, with the research that is known, it does appear to be at significantly less risk than letting a melee continue for several minutes before a response team can be assembled. The current methodologies can result in a ten minute delay that could engender bodily harm well above the risk profile of the proposed system.

Summary

The MTAP feels that adequate safety has been demonstrated to support use of the millimeter wave directed energy system under consideration in the application described. The risks of injury due to the system are minimal relative to the risks of additional injuries that may be sustained by inmates or custodial staff who are subjected to continued physical assault without intervention for a period of 5-10 minutes. There are many unknown factors related to tactical considerations, including highly-motivated aggressors, aggressors with psychiatric conditions, on drugs, or those who are naïve to the weapon, and the ability to employ countermeasures.

Recommendations

At this early stage, based solely on the information presented to this panel on September 23 & 24, 2009, and a similar review by HEAP, it was the consensus of the panel that the technology involved in the “Assault Intervention Device” (also known as Area Denial System [ADS]) to be employed as a prototype device in the corrections setting appears to have minimal and acceptable risks, and appears suitable for pilot implementation and further data collection, with the following caveat:

It was recommended that agencies employing this new technology collect specific and detailed medical and epidemiological data on all use. These data should be reviewed systematically in a timely fashion to allow for a comprehensive assessment to occur.

eXtended Range Electronic Projectile (XREP)

The third meeting of the panel was conducted in an effort to review the eXtended Range Electronic Projectile (XREP). The XREP is a 12 gauge round has two modes of incapacitation, kinetic energy and neuro-muscular incapacitation (NMI). The round was initially marketed as having "the same NMI bio-effect as the handheld X26 but with a range of 20 meters." A complete characterization of the round was being conducted by Wayne State University and these data were presented to the review panel.

In addition, the manufacturer of the XREP, Taser International presented some research data collected internally. Testing was conducted using 1-30 seconds of exposure lengths using the XREP electronics without the use of the barbs. It was stated there was no change in wave form and they are now firing (primer only) inert rounds that could be electrically active remotely. Data was presented for 80 live subjects testing where three drop outs being reported (74 Male, 4 female). Thirty-five had ECGs and 18 had echocardiograms (due to availability of personnel/equipment). Sinus rhythm was only demonstrated in 9 of the 18 subjects.

There were three field cases reported: one in Akron OH, involving a female suspect which was deployed from behind, a Swiss military case fired from X12, and a 3rd case with no engagement (bounced off).

Data was also presented from testing conducted on post-mortem human subjects. The specification defines vulnerable areas as ribs, liver, spleen, intestines and therefore these were the targeted areas. The specimens 2 male torsos, T1-femurs, (46 and 52 years old) with a mass of 165lbs. Forty-three impact locations were conducted: 12 posterior, 14 anterior and 17 anterior. Pre/post testing radiographs were taken. Shots were performed 50-60 mm apart. Energy density was used to assess injury risk, VC max/BC to assess blunt trauma.

Additional data was presented from human subject testing. Subjects (n=62) were given max of 20 second exposure while trying to complete a task. Most did two tests total of 114 tests, hand to abdomen and abdomen to leg are most effective.

There was a discussion in regards to how to setup new monitors to screen for deployment of the XREP. It was suggested that a panel member be identified to interface with local law enforcement agencies to extend an invitation to any agencies that deploying the XREP. It was suggested that an open letter to Tech Beat, Police Chief, Police 1 and maybe Safe Shield might be the best way to contact agencies with the XREP. There was some indication in the quarterly report from Taser that 114 agencies are currently equipped with XREP. It was suggested that a 3 pronged approach be taken; asking Taser for any information available regarding deployment, news search, and reaching out to local agencies.

The long term role of the panel was discussed along with a mission statement. A tentative list of panel members was provided. It was discussed that the panel remain smaller and just invite international members and subject matter experts. There was some discussion of having official invitations be sent out to members with roles, expectations and liabilities. It was also suggested that medical examiners should be added to the list.

Proposed membership of Less Lethal Technologies Medical and Scientific Advisory Panel

Last Name	First Name	Position	Organization
Bir	Cynthia	Professor	Wayne State University
Cecconi	Joseph	Senior Scientist	National Institute of Justice
Hall	Christine	Physician/Researcher	University of British Columbia/ Canadian Police Research Centre
Eastman	Alex	Physician/Researcher	University of Texas Southwestern/ Dallas Police Department
Dennis	Andrew	Physician/Researcher	Rush University/Cook County Hospital/Cook County Sheriff
Smock	Bill	Physician/Researcher	University of Louisville/Louisville Metro Police Department
Kleiner	Doug	Researcher	Wright State University/Hillsboro Beach Police Department
Metzger	Jeffery	Physician/Researcher	University of Texas Southwestern/Dallas Police Department
Heck	Joseph	Physician/Researcher	University of Nevada /Las Vegas Metro Police Department
Bozeman	William	Physician/Researcher	Wake Forest University/Winston Salem Police Department
Smith	Graham	Senior Scientist	Home Office Scientific Development Branch - UK
Palmer	Steve	Executive Director	Canadian Police Research Centre
Hanzlick	Randy	Medical Examiner	Emory University
Gleason	Lisa	Physician/Researcher	San Diego Naval Center

*invited guests as necessary