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Linking Crime Guns: The Impact of Ballistics Imaging Technology on the Productivity of the Boston Police Department's Ballistics Unit*

ABSTRACT: Ballistics imaging technology has received national attention as a potent tool for moving the law enforcement response to violent gun criminals forward by linking multiple crime scenes to one firearm. This study examines the impact of ballistics imaging technology on the productivity of the Boston Police Department's Ballistics Unit. Using negative binomial regression models to analyze times series data on ballistics matches, we find that ballistics imaging technology was associated with a more than sixfold increase in the monthly number of ballistics matches made by the Boston Police Department's Ballistics Unit. Cost-effectiveness estimates and qualitative evidence also suggest that ballistics imaging technology allows law enforcement agencies to make hits that would not have been possible using traditional ballistics methods.

KEYWORDS: forensic science, ballistics imaging, ballistics matching, forensic technology, gun crime, gun enforcement, gun investigations

Every firearm has individual characteristics, akin to the uniqueness of human fingerprints, that are transferred in the form of microscopic scratches and dents to the projectiles and cartridge casings from it (1). The barrel of the firearm marks the bullets that travel through it and the breech mechanism of the firearm marks the ammunition cartridge casings from which the bullets are fired. When bullets and casings are recovered at a crime scene, these unique markings provide law enforcement agencies with an important opportunity to determine whether the bullets or casings were fired from a suspect's firearm. Recovered crime guns can also be test fired and the resulting bullets and casings from one crime scene can be compared with ballistics evidence at another crime scene to determine whether the crimes were linked to the same gun.

In the past, the comparison of ballistics evidence was a very labor-intensive and time-consuming task as each piece of newly recovered evidence had to be manually compared with a potentially vast inventory of recovered or test-fired bullets and casings (1). There was no means to automate the process and, given labor and time constraints, it was very difficult to make matches across crime scenes (1). During the early 1990s, Forensic Technology Inc. developed an automated ballistics imaging and analysis system, called the Integrated Ballistics Identification System (IBIS). The IBIS system maintains a computerized database of digital ballistic images of bullets and casings from crime guns. As new images are entered, IBIS compares the recovered evidence with existing images from prior crime scenes to identify possible matches. For cartridge casings, digital images are correlated based on characteristics such as breech face, firing pin, and ejector marks. For bullets, digital images of the lands (grooves from the rifling of the firearms barrel) are correlated. The IBIS technology quickly sorts through large volumes of ballistics evidence and suggests a small number of candidate cases that may match the evidence in question. Firearms examiners then manually look at the candidate matches and conduct a standard forensic comparison to confirm a match, if one actually exists.

In 1999, the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) and the Federal Bureau of Investigation (FBI) selected IBIS as the standard ballistics imaging technology for their then-proposed National Integrated Ballistics Information Network (NIBIN) (1). Implemented in 2000, NIBIN seeks to unify and coordinate Federal, state, and local law enforcement efforts to use ballistics technology to analyze and match recovered gun crime evidence within a jurisdiction and across different jurisdictions. NIBIN is intended to allow law enforcement to check digital images of recovered ballistic evidence against a nationwide file of many thousands of images of ballistics crime scene evidence. When the deployment is complete, the IBIS technology will be available at 235 sites in 16 multi-state regions covering the entire United States. As of May 2003 the IBIS technology had been received at 222 sites and ATF reported more than 6500 matches or "hits" across the various sites (www.nibin.gov).

The new ballistics imaging technology has received much national attention. ATF has made a concerted effort to publicize the potential value of the technology in advancing its mission of apprehending violent gun criminals. Maryland and New York now have laws requiring ballistics "fingerprinting" of all handguns in their respective states, and gun control advocates call for a national database of ballistic fingerprints for the 200-million-plus firearms in the United States so the firearms used in crime and not recovered by law enforcement can be identified through ballistics imaging analysis (2). Gun rights advocates, however, argue that ballistic image databases are unreliable, expensive, and have little utility in

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solving crimes (3). These critics also suggest that ballistics imaging technology is limited because determined criminals can alter markings on or replace barrels, slides, extractors, and firing pins. These modifications would alter the telltale markings on ballistics evidence and prevent matches from being made.

The available research evidence on the value of the new ballistics imaging technology has mostly focused on the feasibility of creating a statewide ballistics "fingerprinting" system for all firearms. An October 2001 study, led by Frederick Tulleners and conducted for the California Department of Forensic Services, concluded that the workload increase associated with the implementation of a statewide ballistics "fingerprinting" program for all new handgun sales would swamp California's limited number of expert ballistics examiners (4). Since firearms examiners must manually confirm matches based on the candidate-computerized matches suggested by IBIS, the resulting number of potential matches associated with the expanded inventory of ballistics images would be unmanageably large. ATF responded to these findings with its own study suggesting that the brand of ammunition used in the Tulleners study affected the results (5). Jan De Kinder, head of the Ballistics Section of the National Institute for Forensic Sciences in the Belgian Department of Justice, was commissioned by the State of California to peer review the Tulleners study. Dr. De Kinder concluded that the Tulleners assessment was supported by the data in the report as well as by his own analyses in Europe (6).

The use of ballistics imaging technology to examine and compare evidence associated with gun crimes is much less controversial and, due to ATF's concerted efforts, relatively commonplace. However, beyond anecdotal evidence, there is little systematic research evidence that compares the productivity of firearms examiners in linking gun crimes using traditional ballistics methods to the productivity of firearms examiners in linking gun crimes by using the IBIS technology. This study does not attempt to address the accuracy of computerized matching of ballistic images, the value added by expanding ballistic imaging to include non-crime guns, or any other issues in the larger national debate on ballistics imaging technology. Rather, this research examines the impact of ballistics imaging technology on the productivity of the Boston Police Department's (BPD) Ballistics Unit in making ballistics matches across crime scenes.

Use of Ballistics Imaging Technology by the Boston Police Department's Ballistics Unit

Between January 2003 and June 2003, four focus group meetings were convened at the BPD Ballistics Unit to learn about the use of IBIS by the BPD, gain insights on ballistics operations before the adoption of IBIS, frame a research agenda, and discuss available data resources. BPD firearms examiners, detectives, administrators, and research staff attended these meetings. These formative meetings yielded important qualitative insights on BPD ballistics operations over the course of the 1990s and were seminal in guiding our quantitative inquiry in assessing the impact of ballistics imaging technology on the productivity of the Ballistics Unit.

In March 1995, Boston was one of the first major cities to receive the IBIS technology. The system was considered fully implemented when the BPD Ballistics Unit made its first IBIS match in July 1995. Prior to the adoption of IBIS, BPD ballistics operations usually consisted of manually matched bullets and cartridge casings recovered at a crime scene to determine whether the bullets or casings were fired from a suspect's firearm. According to Sergeant James O'Shea, head of the Ballistics Unit and a firearms examiners in the Ballistics Unit did not systematically compare bullets and casings from one scene with ballistics evidence recovered at other crime scenes to determine whether separate gun crimes were linked. When BPD firearms examiners did attempt to make such matches, known as making "cold hits," it happened in one of two ways: (i) the firearms examiner may have recognized some unique markings on a cartridge casing as very similar to markings on a cartridge casing recovered at another crime scene; (ii) a detective would develop an investigative lead from a confidential informant that a recovered crime gun had been used previously in another gun crime and would request the firearms examiner to make comparisons of evidence across the crime scenes.

Since adopting the technology, the BPD test fires all recovered crime guns and the expended bullets and cartridge casings are imaged and entered into the IBIS database. Importantly, the BPD makes an aggressive effort to collect, image, and enter ballistic evidence from all incidents involving firearms, ranging from homicides to illegal possession cases to suicides, into the IBIS database. Only non-crime guns that are held by the BPD for safekeeping are not imaged. The BPD refers to this process as comprehensive imaging of all crime-related ballistics evidence. In sharp contrast, in the pre-IBIS period cartridges and/or bullets from different crimes scenes were cross-examined by ballisticians only in extreme circumstances or where there was a suspicion two criminal events were connected.

Currently, the BPD Ballistics Unit has entered some 2400 bullets and 12,700 cartridge casings into its imaging database as of December 2003, and has recorded 396 confirmed IBIS related matches.[3] Confirmed IBIS matches are a central part of the BPD's interagency Unsolved Shootings Project and Impact Player Assessment meetings. Every two weeks, BPD officers, ATF agents, DEA agents, FBI agents, U.S. Attorneys, and Suffolk County prosecutors review gun crime information to apprehend violent gun criminals and prevent retaliatory violence. Information resources, such as IBIS hits/matches, intelligence from street-level investigators, and strategic analyses of gun crime incidents, play a key role in connecting cases that occur within and across the different Boston Police districts and in the development of intelligence that better focuses Boston gun law enforcement operations.

Data

To measure the impact of the IBIS technology on the productivity of the BPD Ballistics Unit, it is important to consider the nature of the technological innovation and its potential impact on BPD operations. IBIS is able to cross-examine large volumes of evidence and to suggest a small number of candidate cases that may match the evidence in question. The firearms examiner then carefully looks at the candidate cases using standard procedures to determine whether a real match actually exists. The nature of a confirmed match and its utility to a criminal investigation do not change as a result of the IBIS technology. Forensic evidence, such as ballistics matches, is one part of an information chain (eyewitness testimony, circumstantial evidence, etc.) that leads to the ultimate arrest and prosecution of gun criminals. Arrest and prosecution are influenced by many factors beyond the forensic link of a particular gun to ballistics evidence collected at separate crime scenes. Since

[3] According to Sgt. O'Shea, the BPD Ballistics Unit has been imaging ballistics evidence for other local police departments that share gun crime problems with Boston. For example, there are strong street gang connections between Boston and the communities of Brockton (MA), New Bedford (MA), and Providence (RI) and gang-involved gun criminals tend to travel between these cities.

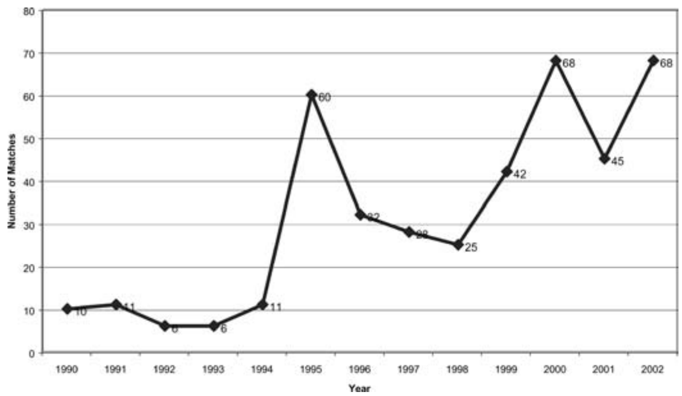

FIG. 1—*Boston Police Department ballistics matches, 1990–2002.*

the value of a ballistics match to the resolution of a crime is not meaningfully different before and after the adoption of IBIS, the outcome of interest is the number of matches made by the Ballistics Unit, not the ultimate disposition of the resulting cases. In essence, this study examines whether IBIS changes the ability of the BPD Ballistics Unit to link gun crimes.

To determine whether the adoption of the IBIS technology was associated with a change in productivity, we examined the annual and monthly number of cold hits made by the BPD Ballistics Unit for the 13-year time period between 1990 and 2002. During the pre-IBIS time period of January 1990 through June 1995, the BPD recorded all ballistics matches in a computerized database. The narrative associated with each recorded match identified the methods used to make the match and this allowed a determination to be made as to whether the match was an IBIS-style cold hit. Since the first IBIS hit in July 1995, the BPD Ballistics Unit recorded the date and month of IBIS hits in logbooks. Unfortunately, hit data for the time period May 1998 and December 1998 are limited. These data were missing from the logbooks due to a temporary disruption in the administrative procedures of the Ballistics Unit during its move to the new BPD headquarters. Documentation from the BPD Youth Violence Strike Force, a primary consumer of IBIS hit information, shows that 20 hits were made by the Ballistics Unit during the time period in question. Unfortunately, the documents did not record the exact date of the matches. We estimated the monthly distribution of the 20 hits by calculating the mean number of hits per month from 1997 and 1999 and distributing the 20 hits across the months accordingly.[4] In our examination of the monthly number of hits, we analyze the data with and without the estimated distribution of the timing of the counts.

Figure 1 presents the yearly number of cold hit ballistic matches made by the BPD Ballistics Unit between 1990 and 2002. During the pre-IBIS period of 1990 through 1994, the Ballistics Unit made an average of 8.8 cold hits per year. After the adoption of IBIS, the productivity of the BPD Ballistics Unit rose dramatically to 60 cold hits in 1995 as the Unit immediately entered a large backlog of ballistics evidence into the system. The yearly number of hits decreased during the 1996–1998 period and, as the inventory of casings in the system grew, increased again between 1999 and 2002. The BPD Ballistics Unit averaged 46 cold hits per year between 1995 and 2002.

[4] For each month, we added the hits from 1997 and 1999 and divided by two. This yielded an average monthly count distribution for the 1998 time period in question. We then distributed the 20 hits across the 8 months dependent on the observed frequencies.

TABLE 1—*Staffing levels of BPD Ballistics Unit, 1993–2002.*

Personnel	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Supervisors	1	1	1	2	2	2	2	2	2	1
Firearm examiners	7	7	7	7	6	5	6	5	5	4
Support staff	1	1	1	1	2	3	3	3	3	4
TOTAL	9	9	9	10	10	10	11	10	10	9

Empirical Analyses

Our analysis of the impact on the monthly number of cold hits made by the BPD Ballistics Unit associated with the adoption of the IBIS technology follows a basic one-group interrupted time series design (7,8). Of course, it would have been ideal to have a control group that did not receive the IBIS technology to make comparisons. However, due to ATF's NIBIN program, there is not a major city comparable to Boston that has a ballistics unit without ballistics imaging technology. In addition, among major cities, Boston showed some of the most dramatic declines in firearms crime (9). This also makes it difficult to find an appropriate control. In absence of a separate control group, the key to a compelling one-group interrupted time series design is the degree to which other forces not related to the intervention influence the outcome variable. If at the time the IBIS technology was introduced in Boston the staff of the Ballistics Unit also changed, this could pose a problem of a change in "instrumentation"(8). However, this was not the case in Boston. As Table 1 shows, the Ballistics Unit staffing level of BPD firearms examiners remained the same before and after the IBIS technology was adopted (see the period 1993 to 1997 in Table 1). Equally important, as confirmed by Sgt. O'Shea, who was the supervisor of the unit at the time IBIS was adopted, there was no change in firearms examiner personnel during this period. More generally, between 1993 and 2002, the Unit had, on average, 6 firearms examiners and 10 total personnel on staff. When the unit lost firearms examiners and a supervisor in the late 1990s due to retirements and a transfer, the Unit acquired additional support staff to maintain operations. The only substantive change in the dynamics of the Ballistics Unit was the addition of the IBIS technology.

For this analysis, we selected July 1995, the month of the first IBIS cold hit match, as the date the IBIS technology was fully implemented. The pre-IBIS time series comprised the monthly counts between January 1990 and June 1995; the post-IBIS time series comprised the monthly counts between July 1995 and December 2002. A binary dummy variable indicating whether the IBIS technology was present or not was constructed to estimate the effects of the intervention on the monthly counts of cold hits. STATA 7.0 statistical software was used to analyze the data.

Monthly counts of cold hits are distributed in the form of rare-event counts. There are well-documented problems associated with treating event count variables, which are discrete, as continuous realizations of a normal data-generating process (10). As such, methods such as standard mean difference tests and ordinary least-squares regression that assume population normality of the dependent variable should not be used to analyze count data (11). Rather, Poisson regression is generally used to estimate models of the event counts (12). The Poisson regression model has the defining characteristic that the conditional mean of the outcome is equal to the conditional variance. However, in practice, the conditional variance often exceeds the conditional mean (12). When a sample count distribution exhibits this "overdispersion," it is unlikely that a Poisson process generated it. Assuming a Poisson process, when the true process generates overdispersed data, results in the same coefficient estimates but underestimates coefficient variances. This results in spuriously large test statistics on the hypothesis that the true coefficient is equal to zero in the population (11). As the analysis demonstrates, the distribution of monthly cold hit counts is overdispersed. When count data are overdispersed, it is appropriate to use the negative binomial generalization of the Poisson regression model. The negative binomial regression model is an extension of the Poisson regression model that allows the conditional variance of the dependent variable to exceed the conditional mean through the estimation of a dispersion parameter (12).

In any time series, there are three sources of noise which could obscure intervention effects: *trend*—the series could drift upwards or downwards; *seasonality*—the series could spike at different times (e.g., gun violence increases in summer months); and *random error*—even if the series was de-trended and de-seasonalized, observations would fluctuate randomly around some mean level (13). If a time series model does not account for these sources of error, the intervention analysis will be confounded. To account for trends in the time series, we included a simple trend variable for linear trends and a trend-squared variable for curvilinear trends.[5] In order to account for seasonal effects in our model, we included dummy variables for each month. We used Auto Regressive Integrated Moving Average (ARIMA) models to detect whether the monthly counts of cold hits were serially autocorrelated (i.e., the number of hits made in January 1990 is significantly correlated with the number of hits in February 1990, and so on) (13).[6] The pre-IBIS time series data did not show significant serial autocorrelation; therefore we did not estimate an AR(1) autoregressive component in our negative binomial model.[7]

It is also important to recognize that the monthly number of hits made by the BPD Ballistics Unit is influenced by the amount of evidence acquired by the Unit every month. Unfortunately, the BPD Ballistics Unit did not maintain an accessible log of the number of pieces of evidence acquired by the Unit before the adoption of the IBIS technology. As such, we use the number of serious gun crimes per month as a proxy variable to control for trends in the amount of evidence acquired by the Unit. Figure 2 shows that the annual number of gun homicides, gun aggravated assaults, and gun robberies in Boston decreased by 58.5%, from 2788 serious gun crimes to 1157 serious gun crimes, between 1990 and 2002.

The parameters for the independent variables were expressed as incidence rate ratios (i.e., exponentiated coefficients). Incidence rate ratios are interpreted as the rate at which things occur; for example, an incidence rate ratio of 0.90 would suggest that, controlling for other independent variables, the selected independent variable would associated with a 10% decrease in the rate at which the dependent variable occurs. To ensure that the coefficient variances were robust to violations of the homoskedastic errors assumption of linear regression models, Huber/White/sandwich robust variance estimators were used. Following social science convention, the two-tailed 0.05 level of significance was selected as the benchmark to reject the null hypothesis of "no difference." The basic model was as follows:

$$\text{Monthly count of hits} = \text{Monthly count of gun crimes} + \text{Trend} + \text{Trend}^2 + \text{IBIS dummy} + \text{Month dummies}$$

Table 2 presents the results of the negative binomial model with and without the estimated distribution of hit data for the time period May 1998 through December 1998. For both estimated models, it is important to note that the coefficient for the alpha dispersion parameter is statistically significant. The significant dispersion parameter confirms that the data were significantly overdispersed and, as such, were distributed as a negative binomial process rather than a Poisson process.[8] In addition for both models, the linear trend,

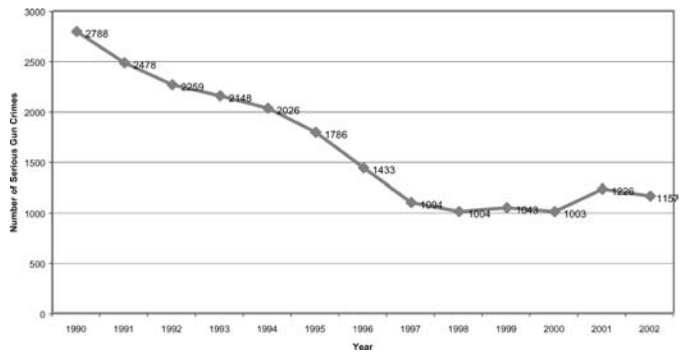

FIG. 2—*Serious gun crime incidents in Boston, 1990–2002 (gun homicides, gun aggravated assaults, gun robberies).*

TABLE 2—*Results of negative binomial regressions (N = 156).*

	Model With Estimated Data	Model Without Estimated Data
IBIS	6.23 (4.29)*	6.18 (4.46)*
Trend	0.99 (−0.14)	0.99 (−0.07)
Trend^2	1.00 (0.66)	1.00 (0.56)
Guncrime	1.01 (1.38)	1.01 (1.24)
Jan	3.03 (3.26)*	3.35 (3.31)*
Feb	2.20 (2.06)*	2.39 (2.16)*
March	1.99 (2.00)*	2.19 (2.11)*
April	2.20 (2.50)*	2.42 (2.56)*
May	2.28 (2.31)*	2.42 (2.20)*
June	2.72 (3.07)*	3.07 (3.09)*
July	3.57 (3.98)*	3.95 (3.88)*
August	2.43 (2.27)*	2.97 (2.76)*
September	2.64 (2.69)*	3.05 (2.87)*
October	2.84 (3.48)*	3.31 (3.63)*
November	1.90 (1.62)	2.35 (2.12)*
Ln alpha	−1.13 (3.56)*	−1.13 (3.52)*
Alpha	0.32 (3.15)*	0.32 (3.11)*
Log likelihood	−288.75	−272.00
Pseudo R^2	0.1338	0.1404
Wald chi-square	140.91	142.14

* $P < 0.05$.

NOTE: Binominal regression model coefficients were expressed as Incidence Rate Ratios with respective Z-scores in parentheses. December was the reference category for the month dummy variables. For both models, the Wald chi-square statistic was distributed with 15 degrees of freedom.

[5] The trend variable was simply the month number from the start to the end of the time series (i.e., for the January 1990 through December 2002 series, the trend variable ranged from 1 to 156). The trend-squared variable was calculated by taking the square of the trend variable.

[6] We pursued these analyses to ensure that we were accounting for possible sources of error in our negative binomial regression models and did not use ARIMA models to measure intervention effects. Identifying appropriate ARIMA models for evaluation purposes can be a very subjective exercise. As Gary Kleck suggests, "Experts in ARIMA modeling also commonly point out difficulties that even experienced practitioners have in specifying time series models. Specification is very much an art rather than a science, so that different researchers, using the same body of data, can make substantially different, even arbitrary decisions, and, as a result, obtain sharply different results" (354) (14).

[7] Using an ARIMA (1,1,1)(1,1,1) model, we did not find significant serial autocorrelation: AR(1) = −0.0341, P = 0.825.

[8] Table 1 reports the z-scores for the test that alpha = 0. Another method to determine whether the data are distributed negative binomial is to calculate

curvilinear trend, and monthly count of serious gun crime variables were not statistically significant. However, the month dummy variables were statistically significant, suggesting seasonal differences in the time series.

Turning to the potential impact of IBIS, we find in the model with the estimated 1998 data, controlling for trends, seasonal variations, and the monthly number of gun crimes, that the adoption of the IBIS technology was associated with a statistically significant 6.23-fold increase in the monthly number of cold hits generated by the BPD Ballistics Unit. In other words, IBIS was associated with 523% more cold hits per month.[9] When the estimated 1998 data are excluded from the analysis, the results of the model remained robust. Controlling for the other independent variables, the adoption of the IBIS technology is still associated with a statistically significant 6.18-fold increase in the monthly number of cold hits generated by the BPD Ballistics Unit.

Estimate of Cost Effectiveness of the IBIS Technology

The cost effectiveness of the IBIS technology in making ballistics matches can be estimated in two ways: the cost of making a match and the cost of comparing a piece of ballistics evidence with the existing inventory of evidence. In 1995, the IBIS equipment used by the BPD cost $540,000. Reflecting general trends in decreasing technology costs, the same equipment cost $295,000 in December 2003. As of December 2003, the BPD Ballistics Unit had made a total of 396 cold hit matches using the IBIS technology. Using 2003 prices, the equipment costs amount to $744.95 per match.[10] There are two reasons to believe that this cost estimate will decrease markedly as time progresses: (i) as more evidence is entered into Boston's IBIS system, the probability of making a hit will increase and the absolute number of hits will continue to increase; and (ii) similar to the costs of other computer-related technologies, the cost of the IBIS technology will also decline over time.

Importantly, IBIS can routinely scan vast inventories of ballistic evidence in a manner that was for most practical purposes impossible prior to the availability of this technology. IBIS technology allows each newly entered piece of ballistics evidence to be compared against existing inventories that can easily be reached in a matter of minutes. Before IBIS, making cold hits was an ad-hoc process that was limited by the ability of firearms examiners to compare selected cartridge casings with the larger inventory of crime scene casings in the property of the Ballistics Unit. For example, in September 1993, Detective John Mulligan was shot execution style five times in the head with a .25 caliber firearm as he sat in his car while working a private security detail at a Walgreens Pharmacy in the Roslindale neighborhood of Boston (16). Deputy Superintendent William Casey, head of the BPD's Information System Group, Sgt. O'Shea, and other members of the focus group reported that, in an attempt to develop more information on the case, the BPD selected fifty .25 cartridge casings from recent violent crimes in the surrounding neighborhood. Five firearm examiners spent ten 8-hr days locating the physical evidence and comparing the selected casings against the recovered crime scene evidence. Unfortunately, this intensive effort did not result in a match. The two suspected killers were arrested after the .25 handgun was found in a vacant lot some 100 yards from the home of one of the suspects in the Dorchester section of Boston.

This anecdote provides an opportunity to estimate the cost of comparing one cartridge casing with the BPD's inventory of cartridge casings. In December 2003, the average BPD firearms examiner earned $50,000 per year. As such, the BPD would pay one firearms examiner $2,083.33 to work ten 8-hr days. Five firearms examiners would cost $10,416.67 for the same time period. As the story describes, the five examiners compared 50 casings with one piece of evidence during this time period. Therefore, it cost the BPD $208.33 to compare two cartridge casings. Assuming the BPD had unlimited resources and firearms examiners, it would cost more than $2.6 million to compare one cartridge casing with every one of the more than 12,700 cartridge casings in the BPD's current inventory.

These figures are not meant to be precise estimates; rather, they simply illustrate that the cost of human examiners routinely scanning existing ballistics inventories for likely matches is prohibitive, and this assumes that human resources are available to make such comparisons. In contrast, the cost of routinely scanning existing ballistics inventories to find potential matches, based solely on the expense of the IBIS equipment, is modest.

The capabilities and cost advantages provided by IBIS technology can significantly increase the use of ballistics evidence by law enforcement. The BPD asserts that the ability of this technology to make quick comparisons against a large inventory of ballistics evidence has yielded a number of high-profile investigations that would not have been possible without IBIS. For example, in 2000, a 9 mm handgun was matched to 15 other gun crimes in Boston, Brockton (MA), Randolph (MA), and Providence (RI) (1). The experience of the BPD also indicates that the use of IBIS technology should be accompanied by a department commitment to comprehensively image all ballistics evidence collected by a law enforcement agency. Without such a commitment, one of the major advantages of IBIS, the ability to routinely scan large-scale inventories of evidence for potential links, is obviously reduced.

Conclusion

The results of this research study suggest that the IBIS technology significantly increased the productivity of the BPD Ballistics Unit. The negative binomial regression analysis found that the adoption of the IBIS technology was associated with a more than 6-fold increase in the number of cold hit matches per month. Clearly, the IBIS technology significantly increases the ability of law enforcement agencies to make ballistics matches across crime scenes. The cost-effectiveness estimates and qualitative evidence also suggest

a likelihood ratio test of whether adding alpha to the count data model significantly improves the fit of the Poisson model to the data. Stata 7.0 calculates this likelihood ratio test when a negative binomial model is run with standard variance estimators (15). Since the reported models were run with robust estimators that assume the errors may have unknown correlation, this likelihood ratio test, which assumes independence, could not be run. However, when the models were run with standard variance estimators, the likelihood ratio tests that alpha = 0 were statistically significant. The chi-square results were 32.29 for the model with the estimated monthly distribution of the limited 1998 data and 31.39 for the model without the estimated 1998 data. These results assert that the probability is zero that these data would be observed conditional on the process being Poisson.

[9] The incidence rate ratio of 6.23 represents the factor that the pre-test number of monthly hits would be multiplied by in order to calculate the estimated effect of IBIS. To calculate the percent increase associated with the difference between the pre-test and post-test periods, 1 has to be subtracted from the factor before multiplying by 100. As such, the incidence rate ratio tells us that the post-test monthly count of cold hits is 6.23 times larger than the pre-test count. This is equivalent to a 523% increase in the monthly number of cold hits.

[10] This estimate is far lower than the cost estimates of $12,000 per cartridge case hit and $195,000 per bullet hit suggested by Kopel and Burnett (3). The difference in estimates is the result of comparing an IBIS system in one jurisdiction that has been operating comprehensively for a number of years with an aggregate of 222 IBIS systems across the United States of which some received the technology only a few months before the Kopel and Burnett report and were not yet fully operational.

that the IBIS technology allows law enforcement agencies to make hits that otherwise would not have been possible. Before IBIS was adopted by the BPD, ballistics matching across gun crime scenes was an ad-hoc and tedious process. Now, the BPD can systematically compare recovered gun crime evidence against its entire inventory of evidence with little effort. The unfortunate 1993 Boston police officer execution-style slaying and the well-known 2000 investigation involving one firearm used in 15 separate incidents provides stark contrasts in the ability of the BPD to link the use of firearms across gun crime scenes.

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