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Abstract: Particularly with the resurgence of concern over police use of deadly force, there is a pressing need to understand the risk factors that lead to police shootings. This study uses a matched-case control design to remove confounders of shooting incidents and identify features of officers that increased their risk of shooting. By matching shooting officers to non-shooting officers at the same scene, the analysis isolates the role of the officers' features from the features of the incident's environment. The study uses data from the New York City Police Department on 291 officers involved in 106 officer-involved shootings adjudicated between 2004 and 2006. Black officers were 3.3 times and officers rapidly accumulating negative marks in their files were 3.1 times more likely to shoot than other officers. Older officers who became police officers later in life were less likely to shoot. The results indicate that officer features related to discharging a firearm are identifiable.

MSC 2010 subject classifications: Primary 62P25.
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1. Introduction

Police use of force is currently the subject of vigorous debate, particularly following the 2014 police shooting death of Michael Brown in Ferguson, Missouri. There is considerable uncertainty concerning the number of deaths from police use of lethal force. The National Violent Death Reporting System suggests a rate of 1.6 deaths per million people per year based on 2005-2011 data from 16 states (Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, 2005), while the Bureau of Justice Statistics reported 2,931 homicides by law enforcement between 2003 and 2009 (Burch, 2011) for an annual rate of 1.4 per million. However, Loftin et al. (2003) noted that law enforcement records and vital statistics can both miss justifiable homicides, though law enforcement report 30% more justifiable homicides than vital statistics. They find 8,658 deaths between 1976 and 1998 for an annual rate of 1.6 deaths per million. Aside from the deaths resulting directly from police shoot-

ings, police shootings can degrade trust in government, with the vast majority of major urban riots in the United States over the past century sparked by grievances over high profile police use-of-force incidents, causing further damage, injury, and deaths.

Decades ago, when researchers were examining questionable shootings (Knoohuizen et al., 1972; Kobler, 1975), they examined the questions of victim race (Kobler, 1975; Inn et al., 1977; Meyer, 1980; Robin, 1963; Takagi, 1974), the victims' involvement in violent crime (Robin, 1963; Copeland, 1986; Fyfe, 1980; Kania and Mackey, 1977; Matulia, 1985; Sherman, 1986), community characteristics (Sherman and Langworthy, 1979), and situational factors that lead to police shootings (White, 2002). While public and prosecutorial attention has turned to the officers involved, existing research has not adequately addressed the question of why some officers are more likely than others to shoot. The sparse research on officer risk factors has suggested at times that age and experience matter (Blumberg, 1989) and at other times that age and experience do not matter (Fyfe, 1978). However, all of the studies trying to explain risk factors are at high risk of unexplained confounding. The officer features associated with shooting risk instead could be the officer features that result in an officer being assigned to a particular precinct, in a particular role, and putting that officer at increased risk of being in the kinds of situations that result in officer-involved shootings (Ho, 1994). While these studies have found interesting associations, we are left wondering whether or not those associations are simply a result of how police officers received their assignments.

In order to better understand and mitigate the risk of police shootings we need to study how attributes of officers involved in the incidents impact the likelihood of lethal force and need to do so in a manner that eliminates confounding due to assignment, place, and context of shootings. Such analyses can improve our understanding of the patterns of police shootings and can help understand how to properly minimize incidents of unnecessary uses of deadly force (Sherman, 1980).

Suppose we were interested in a particular officer feature, being a rookie for example, and its association with the risk of the officer being involved in a shooting. The scientific gold standard would be to somehow randomize rookies and more senior officers to be exposed to different high shooting risk environments and to compare their discharge rates. Such randomization is not plausible. Furthermore, it could eliminate one of the root causes of some shootings, officers getting themselves into situations where they had no other options except to shoot. An alternative might be an observational study that compares shooting rates for all rookies to shooting rates for all other officers. However, any differences we might observe would be highly confounded with assignment to positions that have a large impact on increasing risk (e.g. serving high risk warrants) or decreasing risk (e.g. desk jobs and supervisory positions). In fact, all of the shootings adjudicated during the study period occurred during NYPD's Operation Impact, an initiative in which all freshly minted NYPD officers would be deployed after academy graduation to "impact zones," places in New York City with particularly heavy crime burden (Smith and Purtell, 2007). If the

observed shooting rate for rookies is larger than the rate for other officers we do not want to mistakenly conclude that it is due to lack of experience if the cause is that they are assigned straight out of the academy to crime hotspots. These issues were raised in numerous papers by James Fyfe in his seminal work on the topic.

This study aims to learn which officer features influence risk of shooting and, in doing so, identify officer features that improve our understanding of police shootings and provide policy levers. This study utilizes a matched case-control design, matching shooters to non-shooters on the scene of a shooting incident, to measure the association between officers' risk factors and the shooting risk. This study derives from a more comprehensive review of New York City Police Department (NYPD) firearm policy, training, and discharge review (Rostker et al., 2008).

2. New York City Officer-Involved Shooting Data

This study uses incidence density sampling to form a dataset of officer-involved shootings and the officers on those scenes. For all shootings involving NYPD officers that were adjudicated between 2004 and 2006, I collected data from the NYPD Firearm Discharge Review Board documentation on all officers in the immediate vicinity of the shooting, whether or not they discharged their firearms. There were 184 shootings involving 279 shooters and 194 non-shooters adjudicated during this period. By June 1, 2007, the date all data were extracted, 79 of these officers had left the NYPD and their data had been purged, leaving 239 shooters and 155 non-shooters in 175 incidents. Finally, in 51 incidents there was only one officer on the scene and for 18 incidents all officers on the scene discharged their firearm. Without non-shooters these incidents provide no information for the quantities of interest. The final analytical dataset included data on 106 shooting incidents involving 150 shooters (cases) and 141 non-shooters (controls) matched by incident.

Matching shooters and non-shooters by incident eliminates many sources of confounding. The officers included in the analysis are exactly the kinds of officers that find themselves in situations that lead to shootings - similar times, places, suspects, and calls in which officer-involved shootings occur. If the scenario had evolved differently, such as the suspect running out the back door rather than the front door or a different officer first approached the suspect, then one of the non-shooters on the scene might have become a shooter. We expect some officers in particular instances to fire their guns out of necessity. However, if we consistently find officers with certain features are the shooters in the incident, we may be able to identify risks that can be better managed.

For each officer, the data record numerous risk factors potentially related to shooting risk. Table 1 summarizes these officer features. They include demographics, career history, performance evaluations, arrest history, sick leave, complaints, and firearm range scores. All covariates were calculated for the time of the shooting incident. Demographics include age, race, sex, and education. Work history includes hire date, rank, and command assignments.

Years at NYPD and age are highly correlated ($r = 0.76$). Including both in a regression model would complicate their interpretation. Their principal components suggest an alternative. The first principal component essentially captures longevity (older, more experience). The second principal component had higher values for older officers with less experience. This suggests replacing "age at the time of the shooting" with "age recruited into the NYPD." This transformation results in no loss of information, maintains interpretability of coefficients, and produces a much smaller correlation ($r = 0.32$) than the original pair of officer features.

NYPD conducts performance evaluations annually and records scores on a 0 to 5 scale at 0.5 point increments with higher values indicative of better performance. About 5% of officers receive the highest score and most officers, 82%, receive a score between 3.5 and 4.5. The data also include counts of meritorious awards. Forty percent of officers have at least one medal, averaging about one medal per person every 2.5 years.

NYPD's Central Personnel Index (CPI) maintains a penalty point system for certain negligent or harmful incidents. For example, auto accidents with an NYPD vehicle warrant one point. More serious incidents receive greater penalties: four points for the loss of a badge, six points for losing a firearm, and up to eight points if the officer requires special performance monitoring or receives a suspension. Firearm discharges of any kind always count for one point with the possibility of additional points for performance issues involved in the discharge. For shootings adjudicated between 2004 and 2006, the officers involved in the shootings received between 1 and 15 points with "internal investigations" being the most commonly cited reason for receiving more than 1 point for the shooting. NYPD practice has been that officers that accumulate a career total of 20 points or more are considered for performance monitoring. For this analysis, the data record the total number of CPI points accumulated by the time of the shooting, but do not include any points incurred for the shooting.

The data also include counts for work related activity, including the number of felony and misdemeanor arrests, the number of suspects previously arrested with a gun, days of injury and illness leave (separately for injuries from line of duty and non-line of duty), the number of civilian complaints filed against the officer, and the most recent firearm requalification scores. All count features were converted to annual rates by dividing by the number of years on the job.

As would be expected, Table 1 shows that police officers and detectives are more likely to be shooters than officers in supervisory positions. Few other differences are observable from these marginal summaries with the exception of the CPI point accumulation rate and the sick day rate.

To ease interpretation and to moderate the effect of extreme covariate values, all scores and rates were replaced with an indicator as to whether the value was in the extreme 15% of the distribution. The 15% threshold was selected because it was the most extreme for which the study was still sufficiently powered to detect differences. For the results to have practical impact, thresholds associated with elevated risk can more easily translate into police policy.

TABLE 1
Comparison of Shooting Officers and Non-Shooting Officers on the Scene of an Officer-Involved Shooting, New York City, Cases Adjudicated between 2004-2006

		Shooting officers	Non-shooting officers
	N =	150	141
Rank*	Police officer (%)	65	53
	Detective (%)	17	12
	Sergeant (%)	16	24
	Lieutenant (%)	1	7
	Captain or higher (%)	1	2
Years at NYPD		9.0	9.4
Recruited age		24.9	25.4
Age		33.9	34.8
Race	Black (%)	21	16
	White (%)	59	62
	Other (%)	21	21
Male (%)		94	87
Education	High school (%)	22	17
	High school+some college (%)	59	57
	College (%)	21	21
	College+some graduate (%)	1	2
Command type	Precinct (%)	69	72
	Anti-crime (%)	9	7
	Detective (%)	9	7
	Narcotics (%)	6	6
	Other (%)	7	7
Evaluation score		4.0	4.1
Range score		92.5	92.7
Average annual	Number of medals	2.2	1.6
	Complaints	0.32	0.25
	CPI points*	1.8	1.2
	Gun arrests	1.4	1.1
	Felony arrests	5.0	4.4
	Misdemeanor arrests	6.5	6.1
	Days of sick or injury leave*,1	9.6	6.4
	Not due to line-of-duty	6.4	4.4
	Due to Line-of-duty	3.3	2.1
	Administrative sick leave	1.6	1.7
Percent in excess of 3.1 CPI points/year*		22.0	7.1

* Indicates a statistically significant difference at the 0.05 level
1 Average annual sick leave is based on the most recent five years

3. Conditional Likelihood of Police Shootings

An officer's shooting risk can be modeled as

$$\log \frac{P(S=1|\mathbf{x},\mathbf{z})}{1-P(S=1|\mathbf{x},\mathbf{z})} = h(\mathbf{z}) + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_d x_d \tag{3.1}$$

where S is 1 if the officer shoots and 0 otherwise, $\mathbf{x}$ are the officer's features, and $\mathbf{z}$ are the arbitrarily complex shared features of a particular incident such as the suspects involved, suspect actions, location, and lighting. $h(\mathbf{z})$ represents the baseline shooting risk of a particular scenario. Because each shooting incident consists of matched shooters and non-shooters, $h(\mathbf{z})$ will drop out of the conditional likelihood and never needs to be specified. The model indicates that for a unit increase in x_j, the odds that the officer shoots increases by a factor of $\exp(\beta_j)$.

The dataset, however, is not constructed in a form to estimate the logistic regression model shown in (3.1). A conditional likelihood approach is more compatible with the incidence density sampling approach that formed the dataset. Consider a shooting incident involving two officers, one (officer A) who fired a shot and another (officer B) who did not. This shooting incident would contribute a term to the conditional likelihood

$$P(S_A=1, S_B=0|S_A+S_B=1, \mathbf{x}_A, \mathbf{x}_B, \mathbf{z}) = \frac{e^{\beta'\mathbf{x}_A}}{e^{\beta'\mathbf{x}_A}+e^{\beta'\mathbf{x}_B}}. \tag{3.2}$$

The conditional likelihood is the product of similar terms, more complex for shootings with more than two officers, for each of the shooting incidents. Maximizing the likelihood produces conditional logistic regression estimates of odds-ratios associated with each officer feature (Breslow et al., 1978; Rothman et al., 2008). Even though we drew our samples from $P(\mathbf{x}|S=1,\mathbf{z})$ and $P(\mathbf{x}|S=0,\mathbf{z})$ and estimated the parameters with the conditional likelihood rather than the more typical logistic regression likelihood, the estimates of $\beta_1,\ldots,\beta_d$ from the conditional likelihood are consistent for the odds-ratios of interest (Manski and Lerman, 1977; Prentice and Pyke, 1979). By comparing officers that have in common a scene of a shooting incident, the method completely avoids having to fully specify $\mathbf{z}$ and avoids having to account for the baseline risk of a shooting.

3.1. Contagious Fire

In order to simplify the conditional likelihood term as shown in (3.2), we must assume that, given the officers' features and the features of the scenario, the probability that an officer shoots is independent of whether the other officers shoot. Without this assumption, $h(\mathbf{z})$ does not drop out of the likelihood. Some have speculated about "contagious fire," that an officer fires because another officer on the scene has fired (Wilson, 2006). In 75% of incidents only one officer shoots, but in the other 25% up to eight officers shoot. Contagion elevates shooting risk for all officers on the scene subsequent to the first shot fired. Contagious

fire would result in more shooting incidents dropping out of the likelihood since it will increase the chance that all officers on the scene shoot. Recall that 18 of the incidents in the dataset dropped out of the likelihood because all officers discharged their firearm. Even with contagion the estimated coefficients will still be in the right direction, but may have a different interpretation. That is, depending on the magnitude of contagion, the estimates may differ from the model described in (3.1). However, they can always be interpreted in the conditional likelihood context, given that a shooting occurs how much more likely is it that an officer with $x = 1$ is the shooter compared to an officer with $x = 0$.

Contagion's effect on the null distribution of the coefficients is more complex. To avoid relying on parametric assumptions, I used permutation tests to construct reference distributions for each parameter in the model. For each officer feature, the permutation tests randomly shuffled the shooting indicator *within each shooting incident* 10,000 times. For each permuted dataset, I refit a conditional logistic regression model. The resulting distribution of coefficient estimates is a valid reference distribution for the coefficients under the hypothesis that the covariates are unrelated to shooting risk. The permutation test p-value is computed as the fraction of simulations having the absolute value of the coefficients as or more extreme than the observed coefficient.

4. Data Analysis

Table 2 shows the estimated odds-ratios and associated 95% confidence intervals from the conditional logistic regression model. Table 2 also shows the associated permutation p-values.

Middle management rank officers were significantly less likely than police officers to shoot ($P < 0.01$). This is reasonable as sergeants and lieutenants on the scene are much more likely to be in supervisory or command positions rather than directly involved in an situation, although there were 24 sergeants, 2 lieutenants, and 2 captains who discharged their weapons. The confidence intervals for the odds-ratio for captains based on normal theory do not overlap 1.0. However, the more reliable permutation test p-value suggests no significant difference for captains ($P = 0.16$).

Officers were 10% times less likely to shoot than similar officers who were 1 year younger than them when recruited ($P = 0.03$). Years of experience had no association with shooting risk. This suggests that reductions in shooting risk might be obtainable by increasing minimum age requirements or more heavily targeting police recruiting efforts toward older candidates who come to policing later in their working years.

Black officers were 3.3 times more likely to shoot than white officers ($P = 0.01$). While substantial public concern comes from shootings involving white officers and black victims, this study shows that white officers are more than three times less likely to discharge their firearms compared to black officers on the scene of the same incident. This finding is consistent with previous research showing black officers killed felons at much higher rates than white police officers

TABLE 2
Matched Case-Control Analysis of Shooting Officers and Non-Shooting Officers on the Scene of Police Shootings, New York City, Cases Adjudicated between 2004-2006

Variable	Odds-ratio	95% interval	Permutation p-value
Rank			
Police officer (reference)			
Detective	1.2	(0.2,6.3)	0.78
Sergeant	*0.2	(0.1,0.7)	0.006
Lieutenant	*0.0	(0.0,0.4)	0.003
Captain[2]	0.1	(0.0,0.8)	0.16
Years at NYPD	1.0	(0.9,1.1)	0.89
Age when recruited	*0.9	(0.8,1.0)	0.03
Race			
White (reference)			
Black	*3.3	(1.2,8.9)	0.01
Other	1.2	(0.5,2.8)	0.71
Male	2.1	(0.5,8.9)	0.29
Education			
High school (reference)			
High school+some college	1.3	(0.5,3.0)	0.60
College	1.9	(0.6,6.1)	0.26
College+some graduate	1.8	(0.1,22.7)	0.68
Precinct officer[2]	0.2	(0.0,1.2)	0.08
Average annual			
Evaluation score < 3.5	0.7	(0.3,1.8)	0.45
Range score < 86	1.8	(0.7,4.5)	0.16
Complaints > 0.6	2.1	(0.7,6.4)	0.15
Medal count/year > 3.8	2.3	(0.5,9.5)	0.21
CPI points > 3.1	*3.1	(1.0,8.9)	0.03
Gun arrests > 2.4	0.7	(0.2,2.5)	0.64
Felony arrests > 9.3	2.1	(0.6,7.0)	0.20
Misdemeanor arrests > 10.0	*0.2	(0.1,0.6)	0.002
Days of leave			
Not due to line of duty injury > 8.4	0.9	(0.4,2.1)	0.81
Due to line of duty injury > 5.6	0.9	(0.3,2.4)	0.82

* Indicates a statistically significant difference at the 0.05 level
[1] Although the confidence interval based on normal theory does not overlap 1.0, the non-parametric permutation test p-value is well above 0.05 and, therefore, this feature is not flagged as significant
[2] Precinct officers are assigned to precincts without special assignments (e.g. not assigned to anti-crime, detectives, housing, task forces, etc.)

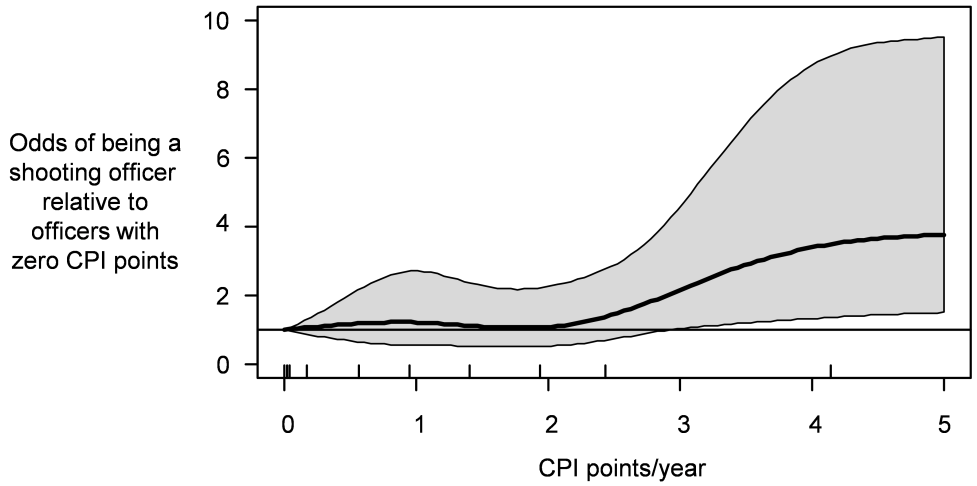

FIG 1. *Relationship Between an Officer's CPI Points per Year and the Odds of Shooting, New York City, Cases Adjudicated between 2004-2006*

in a national sample (Sorensen et al., 1993) and that black officers shot black suspects at substantially higher rates in Chicago (Geller and Karales, 1981). This study makes no judgment on the appropriateness of the shootings or whether the findings in New York would be consistent in other communities.

Officers accumulating more than 3.1 CPI points per year were 3.1 times more likely to be shooters ($P = 0.03$). A high CPI point rate may be indicative of poor judgment. It may also be indicative of the proactive officer, the ones that take important but perilous actions but in the process increase their risk of accumulating CPI points and getting into the position of making shoot/don't shoot decisions. NYPD practice has been to monitor closely officers who accumulate CPI points in excess of 20, but this analysis suggests that the rate of accumulating CPI points is a stronger indicator of shooting risk than the total number of CPI points.

The significance of CPI points is particularly relevant since it relates prior problematic performance with shooting risk. Figure 1 shows how the odds of shooting vary with the CPI points rate using a natural spline transformation of the CPI points rate. Officers with CPI point rates anywhere between 0 and 2 appear to be at no greater risk for shooting. However, above 2 CPI points per year, shooting risk appears to increase by 50% for each additional CPI point per year.

Officers who were more actively involved in making misdemeanor arrests, making more than ten misdemeanor arrests per year, were four times less likely to shoot than officers with a slower pace of misdemeanor arrests ($P = 0.002$). It is possible that these officers are accustomed to misdemeanor arrests that rarely require police use-of-force and, therefore, when in a setting in which other

officers perceive the need to shoot, these officers are operating according to their familiar "no need for force" standard.

Table 2 indicates a general pattern that was also present in Table 1; shooting officers are more active, receiving more medals, making more felony arrests, and missing more days of work from being injured in the line of duty. This pattern's implications for the NYPD and for public safety is complicated. If, for instance, this pattern is a result of headstrong officers, it would suggest the possibility that some of the shootings were problematic, and NYPD would want to develop strategies for identifying officers with poor judgment to ensure that they do not have assignments in which they might do harm. On the other hand, if the pattern is the result of proactivity, then the department and the public probably does not want to suppress such officers but effort might be required to make sure they are in fact proactive rather than headstrong.

5. Conclusions

This matched case-control study of 106 NYPD officer-involved shootings identified four key officer features associated with the risk of shooting.

- Officers who join NYPD later in their careers have a lower shooting risk. Several police departments have struggled with meeting recruiting objectives and have lowered the minimum age even though research has indicated that younger officers are at higher risk for disciplinary issues (Taylor et al., 2005). The finding from this study further supports this view; recruiting older officers may reduce the frequency of police shootings.
- Black officers had more than three times greater odds of shooting than white officers. This finding runs counter to concerns that white officers are overrepresented among officers using lethal force, but is consistent with numerous previous studies of officer race and police use-of-force. Police legitimacy requires communities to diversify their police departments to make them more representative of the citizens served. However, a deeper understanding of police officer race is necessary since recent research suggests diversity does not make officers safer (Barrick et al., 2014) and this research does not suggest diversity will reduce the risk of police shootings. The greatest challenge that this finding poses is that, unlike other findings, it offers nothing actionable that a police department can or should do to mitigate shooting risk.
- Officers rapidly accumulating negative marks in their file are at more than three times greater risk of shooting. This indicates that police executives aiming to ensure that their officers are not exercising unnecessary use of deadly force can monitor the accumulation negative marks as a leading indicator for shooting risk and may adopt training and assignment policies to mitigate that risk.
- Officers who made numerous misdemeanor arrests were four times less likely to shoot. This possibly suggests that frequent interaction with misdemeanor arrestees sets the officer's baseline risk of shooting lower than

colleagues without that experience. Officers frequently engaged in arrests not requiring use-of-force may calibrate their perceived risk differently than other officers. Assuming that these arrest activities do not calibrate their perceived risk to be too low, this finding suggests that rotating officers to assignments producing frequent misdemeanor arrests can help reduce shooting risk.

Police shootings are responsible for about 400 to 500 fatalities per year. In addition, police shootings can greatly disrupt communities from the intangible "public trust in justice" to the tangible civil unrest and associated damage and injury. In order to minimize the risk of police shootings, we need a better understanding of the factors that elevate the risk of shootings. The approach used in this study relies on a conditional likelihood model to identify the association between officer features and their risk of shooting, removing potential confounding for time, place, and context of the incident and revealed strong associations between the age officers are recruited, race, officer performance, officer arrest history and shooting risk. This approach overcomes confounding obstacles that have undercut the conclusions of previous studies of officer-involved shootings.

This study also demonstrates that a statistical approach can address concerns about police use-of-force. In fact, other use-of-force incidents, such as conductive energy device (Tasers) usage (MacDonald et al., 2009), are more common and, therefore, will result in analyses with greater statistical power. The inclusion of additional covariates including specific types of training that officers have received or their scores on recruiting standards can help departments understand the merits of training programs and the suitability of recruiting standards. With rich data sources and appropriate statistical methodologies we can identify risks for shootings, the first step in mitigating future officer-involved shootings and heading off future civil unrest.

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